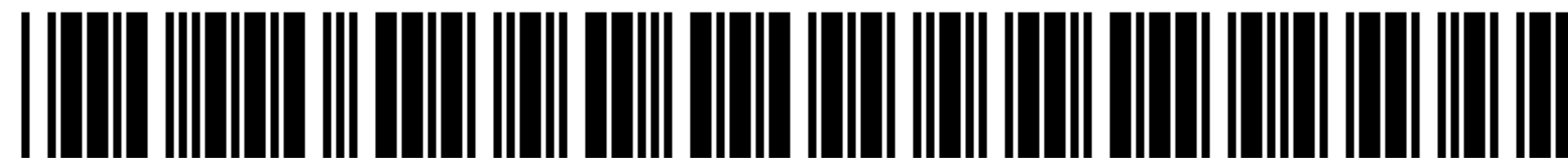


Exhibit 2



US010491748B1

(12) **United States Patent**
Wu et al.

(10) **Patent No.: US 10,491,748 B1**
(45) **Date of Patent: Nov. 26, 2019**

(54) **INTELLIGENT COMMUNICATION
ROUTING SYSTEM AND METHOD**

(71) Applicants: **Wai Wu**, Massapequa, NY (US);
Steven M. Hoffberg, West Harrison,
NY (US)

(72) Inventors: **Wai Wu**, Massapequa, NY (US);
Steven M. Hoffberg, West Harrison,
NY (US)

(*) Notice: Subject to any disclaimer, the term of this
patent is extended or adjusted under 35
U.S.C. 154(b) by 51 days.

(21) Appl. No.: **15/797,070**

(22) Filed: **Oct. 30, 2017**

Related U.S. Application Data

(60) Division of application No. 14/968,114, filed on Dec.
14, 2015, now Pat. No. 9,807,239, which is a
(Continued)

(51) **Int. Cl.**
H04M 3/00 (2006.01)
H04M 5/00 (2006.01)
(Continued)

(52) **U.S. Cl.**
CPC **H04M 3/5233** (2013.01); **H04L 29/06027**
(2013.01)

(58) **Field of Classification Search**
CPC H04M 3/5191; H04M 3/5232; H04M
3/5183; H04M 3/5175; H04M 3/5233;
H04M 3/5166; H04M 3/24; H04M
3/5235; H04M 3/5141; H04M 2201/42;
H04M 3/5133; H04M 3/28; H04M
2203/402; H04M 3/523; H04M 2203/408;
H04M 2203/556; G06Q 10/067; G06Q
10/04; G06Q 10/06; G06Q 10/0631;

G06Q 10/06312; G06Q 10/06313; G06Q
30/0201; G06Q 30/0202; H04L 43/06;
H04L 43/50; H04L 51/046; H04L 41/14
USPC 379/265.11, 265.01, 265.02, 265.09,
379/265.03, 265.06, 265.13, 265.05, 272,
379/10.01, 265.1, 265.12, 265.14
See application file for complete search history.

(56) References Cited

U.S. PATENT DOCUMENTS

2,906,027 A 9/1959 Gundersen et al.
3,974,275 A 8/1976 Bossert et al.
(Continued)

FOREIGN PATENT DOCUMENTS

WO WO 20050290297 9/2018

OTHER PUBLICATIONS

US 5,415,368 A, 05/1995, Horstein et al. (withdrawn)

Primary Examiner — Quynh H Nguyen

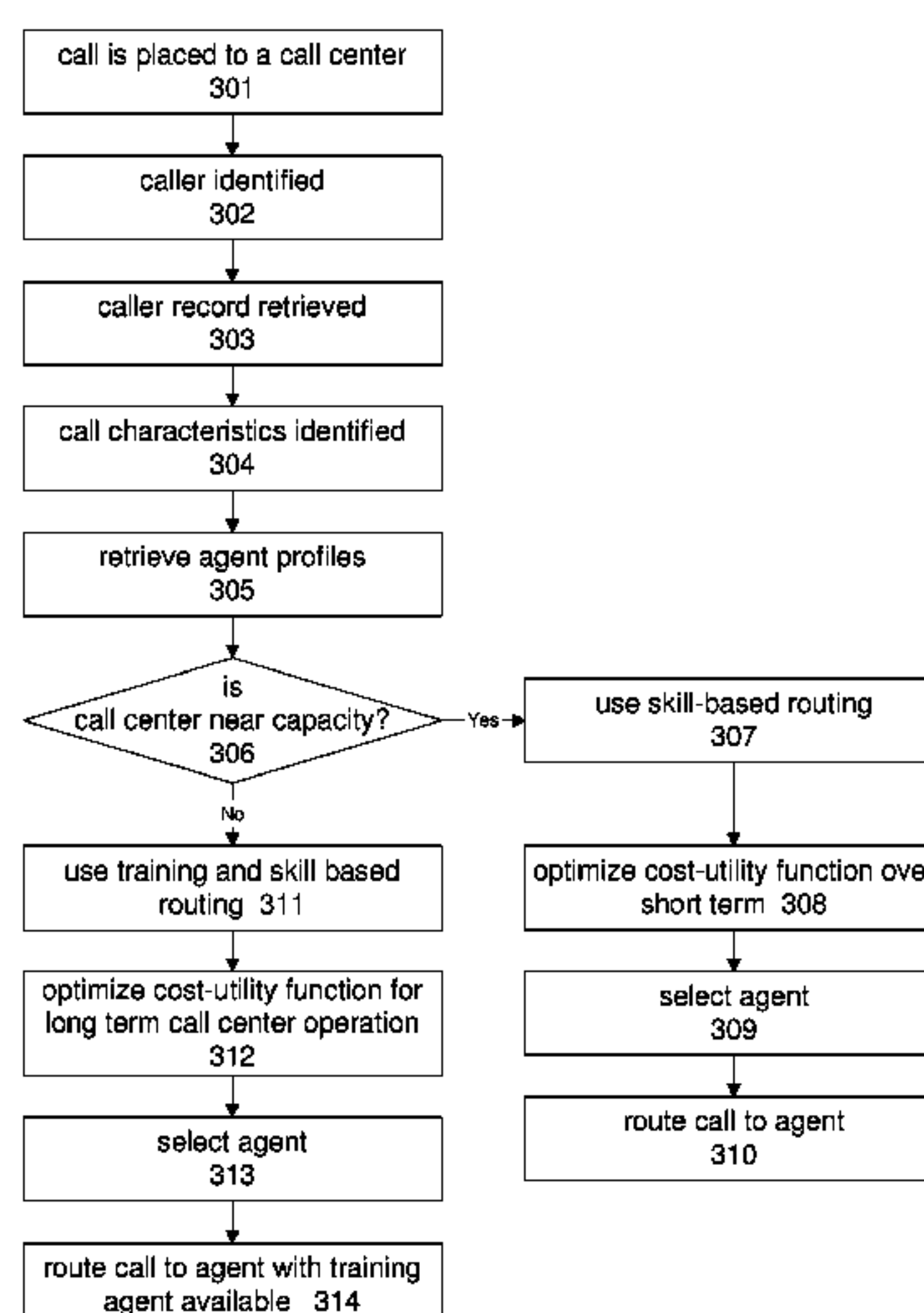
Assistant Examiner — Kharye Pope

(74) *Attorney, Agent, or Firm* — Tully Rinckey PLLC;
Steven M. Hoffberg; Steven Hoffberg

(57) ABSTRACT

A communications routing system, and method, for repre-
senting a plurality of predicted characteristics of a plurality
of communications sources, each having an economic util-
ity; representing a plurality of predicted characteristics of a
plurality of communications targets each having an eco-
nomic utility; and determining an optimal routing between
the plurality of communications sources and the plurality of
communications targets, by maximizing an aggregate utility
with respect to the respective predicted characteristics of
communications source and communications destination
represented by linkages.

20 Claims, 9 Drawing Sheets



US 10,491,748 B1

Related U.S. Application Data			5,020,097 A	5/1991	Tanaka et al.
continuation of application No. 13/661,293, filed on			5,021,945 A	6/1991	Morrison et al.
Oct. 26, 2012, now Pat. No. 9,215,322, which is a			5,036,535 A	7/1991	Gechter et al.
continuation of application No. 11/695,691, filed on			5,040,208 A	8/1991	Jolissaint
Apr. 3, 2007, now Pat. No. 8,300,798.			5,048,075 A	9/1991	Katz
			5,051,984 A	9/1991	Mostafa et al.
			5,056,085 A	10/1991	Vu
			5,058,105 A	10/1991	Mansour et al.
			5,063,522 A	11/1991	Winters
(60)	Provisional application No. 60/744,190, filed on Apr.		5,065,399 A	11/1991	Hasegawa et al.
3, 2006.			5,070,498 A	12/1991	Kakuma et al.
(51)	Int. Cl.		5,070,525 A	12/1991	Szlam et al.
	<i>H04M 3/523</i>	(2006.01)	5,070,526 A	12/1991	Richmond et al.
	<i>H04L 29/06</i>	(2006.01)	5,073,890 A	12/1991	Danielsen
	<i>H04L 12/66</i>	(2006.01)	5,073,900 A	12/1991	Mallinckrodt
			5,073,929 A	12/1991	Katz
			5,077,789 A	12/1991	Clark, Jr. et al.
(56)	References Cited		5,081,703 A	1/1992	Lee
			5,081,711 A	1/1992	Rickman, Jr.
			5,088,032 A	2/1992	Bosack
			5,093,794 A	3/1992	Howie et al.
			5,097,528 A	3/1992	Gursahaney et al.
			5,103,449 A	4/1992	Jolissaint
			5,109,390 A	4/1992	Gilhousen et al.
			5,115,495 A	5/1992	Tsuchiya et al.
			5,119,225 A	6/1992	Grant et al.
			5,121,325 A	6/1992	DeJonge
			5,121,422 A	6/1992	Kudo
			5,126,748 A	6/1992	Ames et al.
			5,128,926 A	7/1992	Perlman et al.
			5,128,984 A	7/1992	Katz
			5,134,715 A	7/1992	Parl et al.
			5,146,452 A	9/1992	Pekarske
			5,161,181 A	11/1992	Zwick
			5,163,083 A	11/1992	Dowden et al.
			5,163,087 A	11/1992	Kaplan
			5,164,981 A	11/1992	Mitchell et al.
			5,166,974 A	11/1992	Morganstein et al.
			5,168,517 A	12/1992	Waldman
			5,173,689 A	12/1992	Kusano
			5,175,800 A	12/1992	Galis et al.
			5,175,866 A	12/1992	Childress et al.
			5,179,329 A	1/1993	Nishikawa et al.
			5,179,527 A	1/1993	Lawrenz
			5,179,556 A	1/1993	Turner
			5,182,744 A	1/1993	Askew et al.
			5,185,786 A	2/1993	Zwick
			5,193,110 A	3/1993	Jones et al.
			5,199,027 A	3/1993	Barri
			5,206,903 A	4/1993	Kohler et al.
			5,214,688 A	5/1993	Szlam et al.
			5,216,427 A	6/1993	Yan et al.
			5,218,601 A	6/1993	Chujo et al.
			5,218,635 A	6/1993	Bonvallet et al.
			5,218,676 A	6/1993	Ben-Ayed et al.
			5,224,153 A	6/1993	Katz
			5,224,162 A	6/1993	Okamoto et al.
			5,228,025 A	7/1993	Le Floch et al.
			5,233,600 A	8/1993	Pekarske
			5,233,604 A	8/1993	Ahmadi et al.
			5,233,626 A	8/1993	Ames
			5,235,599 A	8/1993	Nishimura et al.
			5,237,159 A	8/1993	Stephens et al.
			5,237,514 A	8/1993	Curtin
			5,239,574 A	8/1993	Brandman et al.
			5,239,671 A	8/1993	Linguist et al.
			5,251,147 A	10/1993	Finnerty
			5,251,252 A	10/1993	Katz
			5,253,248 A	10/1993	Dravida et al.
			5,253,289 A	10/1993	Tanaka
			5,255,349 A	10/1993	Thakoor et al.
			5,263,080 A	11/1993	Jones et al.
			5,265,092 A	11/1993	Soloway et al.
			5,265,119 A	11/1993	Gilhousen et al.
			5,267,232 A	11/1993	Katsube et al.
			5,270,919 A	12/1993	Blake et al.
			5,271,005 A	12/1993	Takase et al.
			5,272,638 A	12/1993	Martin et al.
			5,274,643 A	12/1993	Fisk

US 10,491,748 B1

Page 3

(56)

References Cited

U.S. PATENT DOCUMENTS

5,276,732 A	1/1994	Stent et al.	5,471,647 A	11/1995	Gerlach et al.
5,278,898 A	1/1994	Cambray et al.	5,479,444 A	12/1995	Malkamaki et al.
5,283,818 A	2/1994	Klausner et al.	5,479,447 A	12/1995	Chow et al.
5,287,541 A	2/1994	Davis et al.	5,479,487 A	12/1995	Hammond
5,289,303 A	2/1994	Cloonan et al.	5,479,501 A	12/1995	Lai
5,289,530 A	2/1994	Reese	5,481,596 A	1/1996	Comerford
5,289,536 A	2/1994	Hokari	5,485,506 A	1/1996	Recht et al.
5,291,550 A	3/1994	Levy et al.	5,491,690 A	2/1996	Alfonsi et al.
5,297,146 A	3/1994	Ogawa	5,493,690 A	2/1996	Shimazaki
5,297,195 A	3/1994	Thorne et al.	5,495,426 A	2/1996	Waclawsky et al.
5,303,286 A	4/1994	Wiedeman	5,495,479 A	2/1996	Galaand et al.
5,309,504 A	5/1994	Morganstein	5,495,523 A	2/1996	Stent et al.
5,309,505 A	5/1994	Szlam et al.	5,495,528 A	2/1996	Dunn et al.
5,309,513 A	5/1994	Rose	5,502,762 A	3/1996	Andrew et al.
5,311,502 A	5/1994	Mueller et al.	5,502,816 A	3/1996	Gawlick et al.
5,311,574 A	5/1994	Livanos	5,504,837 A	4/1996	Griffeth et al.
5,311,577 A	5/1994	Madrid et al.	5,506,898 A	4/1996	Costantini et al.
5,313,516 A	5/1994	Afshar et al.	5,510,779 A	4/1996	Maltby et al.
5,315,584 A	5/1994	Savary et al.	5,510,799 A	4/1996	Wishart
5,319,703 A	6/1994	Drory	5,511,112 A	4/1996	Szlam
5,321,745 A	6/1994	Drory et al.	5,511,117 A	4/1996	Zazzera
5,321,815 A	6/1994	Bartolanzo, Jr. et al.	5,511,121 A	4/1996	Yacobi
5,325,292 A	6/1994	Crockett	5,515,367 A	5/1996	Cox, Jr. et al.
5,325,472 A	6/1994	Horiuchi et al.	5,515,378 A	5/1996	Roy, III et al.
5,327,490 A	7/1994	Cave	5,515,421 A	5/1996	Sikand et al.
5,329,579 A	7/1994	Brunson	5,517,566 A	5/1996	Smith et al.
5,333,190 A	7/1994	Eyster	5,517,628 A	5/1996	Morrison et al.
5,339,330 A	8/1994	Mallinckrodt	5,519,773 A	5/1996	Dumas et al.
5,341,412 A	8/1994	Ramot et al.	5,519,836 A	5/1996	Gawlick et al.
5,341,414 A	8/1994	Popke	5,521,591 A	5/1996	Arora et al.
5,345,444 A	9/1994	Cloonan et al.	5,521,616 A	5/1996	Capper et al.
5,345,599 A	9/1994	Paulraj et al.	5,524,140 A	6/1996	Klausner et al.
5,351,285 A	9/1994	Katz	5,524,147 A	6/1996	Bean
5,357,507 A	10/1994	Hughes et al.	5,526,414 A	6/1996	Bedard et al.
5,359,593 A	10/1994	Derby et al.	5,526,417 A	6/1996	Dezonno
5,359,645 A	10/1994	Katz	5,528,666 A	6/1996	Weigand et al.
5,359,649 A	10/1994	Rosu et al.	5,530,931 A	6/1996	Cook-Hellberg et al.
5,365,575 A	11/1994	Katz	5,532,939 A	7/1996	Psinakis et al.
5,369,695 A	11/1994	Chakravarti et al.	5,533,103 A	7/1996	Peavey et al.
5,377,262 A	12/1994	Bales et al.	5,533,107 A	7/1996	Irwin et al.
5,381,404 A	1/1995	Sugano et al.	5,533,108 A	7/1996	Harris et al.
5,381,470 A	1/1995	Cambray et al.	5,533,109 A	7/1996	Baker
5,390,170 A	2/1995	Sawant et al.	5,535,257 A	7/1996	Goldberg et al.
5,390,236 A	2/1995	Klausner et al.	5,537,435 A	7/1996	Carney et al.
5,392,353 A	2/1995	Morales	5,537,470 A	7/1996	Lee
5,394,324 A	2/1995	Clearwater	5,539,815 A	7/1996	Samba
5,400,393 A	3/1995	Knuth et al.	5,539,884 A	7/1996	Robrock, II
5,402,474 A	3/1995	Miller et al.	5,544,220 A	8/1996	Trefzger
5,408,663 A	4/1995	Miller	5,544,232 A	8/1996	Baker et al.
5,410,586 A	4/1995	Davies	5,546,452 A	8/1996	Andrews et al.
5,410,728 A	4/1995	Bertiger et al.	5,546,456 A	8/1996	Vilsoet et al.
5,420,852 A	5/1995	Anderson et al.	5,548,639 A	8/1996	Ogura et al.
5,420,919 A	5/1995	Arnaud et al.	5,548,801 A	8/1996	Araki et al.
5,422,647 A	6/1995	Hirshfield et al.	5,548,819 A	8/1996	Robb
5,425,093 A	6/1995	Trefzger	5,551,624 A	9/1996	Horstein et al.
5,430,729 A	7/1995	Rahnema	5,555,290 A	9/1996	McLeod et al.
5,430,792 A	7/1995	Jesurum et al.	5,555,295 A	9/1996	Bhusri
5,432,835 A	7/1995	Hashimoto	5,557,668 A	9/1996	Brady
5,433,726 A	7/1995	Horstein et al.	5,559,707 A	9/1996	DeLorme et al.
5,434,906 A	7/1995	Robinson et al.	5,559,867 A	9/1996	Langsenkamp et al.
5,436,967 A	7/1995	Hanson	5,559,877 A	9/1996	Ash et al.
5,439,190 A	8/1995	Horstein et al.	5,559,878 A	9/1996	Keys et al.
5,442,693 A	8/1995	Hays et al.	5,560,011 A	9/1996	Uyama
5,446,756 A	8/1995	Mallinckrodt	5,561,711 A	10/1996	Muller
5,448,623 A	9/1995	Wiedeman et al.	5,566,209 A	10/1996	Forssen et al.
5,448,624 A	9/1995	Hardy et al.	5,566,283 A	10/1996	Modegi et al.
5,448,631 A	9/1995	Cain	5,568,540 A	10/1996	Greco et al.
5,452,294 A	9/1995	Natarajan	5,570,419 A	10/1996	Cave et al.
5,459,716 A	10/1995	Fahim et al.	5,572,430 A	11/1996	Akasaka et al.
5,459,781 A	10/1995	Kaplan et al.	5,572,576 A	11/1996	Klausner et al.
5,463,686 A	10/1995	Lebourges	5,572,586 A	11/1996	Ouchi
5,465,204 A	11/1995	Sekine et al.	5,574,784 A	11/1996	LaPadula et al.
5,465,286 A	11/1995	Clare et al.	5,577,112 A	11/1996	Cambray et al.
5,467,391 A	11/1995	Donaghue, Jr. et al.	5,579,377 A	11/1996	Rogers
5,471,467 A	11/1995	Johann	5,579,383 A	11/1996	Bales et al.
			5,581,602 A	12/1996	Szlam et al.
			5,581,604 A	12/1996	Robinson et al.
			5,581,607 A	12/1996	Richardson, Jr. et al.
			5,586,179 A	12/1996	Stent et al.

US 10,491,748 B1

Page 4

(56)

References Cited

U.S. PATENT DOCUMENTS

5,586,267 A	12/1996	Chatwani et al.	5,724,418 A	3/1998	Brady
5,588,049 A	12/1996	Detering et al.	5,727,051 A	3/1998	Holender
5,590,171 A	12/1996	Howe et al.	5,727,154 A	3/1998	Fry et al.
5,590,188 A	12/1996	Crockett	5,727,221 A	3/1998	Walsh et al.
5,592,469 A	1/1997	Szabo	5,729,600 A	3/1998	Blaha et al.
5,592,490 A	1/1997	Barratt et al.	5,729,720 A	3/1998	Kau et al.
5,592,543 A	1/1997	Smith et al.	5,734,919 A	3/1998	Walsh et al.
5,594,790 A	1/1997	Curreri et al.	5,737,685 A	4/1998	Locascio et al.
5,594,791 A	1/1997	Szlam et al.	5,740,164 A	4/1998	Liron
5,596,722 A	1/1997	Rahnema	5,740,233 A	4/1998	Cave et al.
5,598,532 A	1/1997	Liron	5,740,240 A	4/1998	Jolissaint
5,600,638 A	2/1997	Bertin et al.	5,740,366 A	4/1998	Mahany et al.
5,600,710 A	2/1997	Weisser, Jr. et al.	5,742,675 A	4/1998	Kilander et al.
5,608,721 A	3/1997	Natarajan et al.	5,748,611 A	5/1998	Allen et al.
5,610,774 A	3/1997	Hayashi et al.	5,748,711 A	5/1998	Scherer
5,610,908 A	3/1997	Shelswell et al.	5,751,987 A	5/1998	Mahant-Shetti et al.
5,610,978 A	3/1997	Purits	5,752,173 A	5/1998	Tsujimoto
5,612,701 A	3/1997	Dickelman	5,754,436 A	5/1998	Walsh et al.
5,616,078 A	4/1997	Oh	5,754,790 A	5/1998	France et al.
5,617,514 A	4/1997	Dolby et al.	5,754,837 A	5/1998	Walsh et al.
5,619,557 A	4/1997	Van Berkum	5,754,939 A	5/1998	Herz et al.
5,619,695 A	4/1997	Arbabi et al.	5,761,285 A	6/1998	Stent
5,621,201 A	4/1997	Langhans et al.	5,764,740 A	6/1998	Holender
5,623,413 A	4/1997	Matheson et al.	5,765,037 A	6/1998	Morrison et al.
5,623,547 A	4/1997	Jones et al.	5,768,355 A	6/1998	Salibrici et al.
5,625,676 A	4/1997	Greco et al.	5,768,360 A	6/1998	Reynolds et al.
5,625,682 A	4/1997	Gray et al.	5,768,385 A	6/1998	Simon
5,625,867 A	4/1997	Rouffet et al.	5,771,373 A	6/1998	Kau et al.
5,625,868 A	4/1997	Jan et al.	5,774,357 A	6/1998	Hoffberg et al.
5,627,889 A	5/1997	Eslambolchi	5,774,526 A	6/1998	Propp et al.
5,629,838 A	5/1997	Knight et al.	5,774,537 A	6/1998	Kim
5,633,917 A	5/1997	Rogers	5,781,780 A	7/1998	Walsh et al.
5,633,922 A	5/1997	August et al.	5,784,291 A	7/1998	Chen et al.
5,633,924 A	5/1997	Kaish et al.	5,784,636 A	7/1998	Rupp
5,634,199 A	5/1997	Gerlach et al.	5,787,156 A	7/1998	Katz
5,636,267 A	6/1997	Utsumi et al.	5,787,159 A	7/1998	Hamilton et al.
5,636,268 A	6/1997	Dijkstra et al.	5,787,271 A	7/1998	Box et al.
5,638,436 A	6/1997	Hamilton et al.	5,787,470 A	7/1998	DeSimone et al.
5,642,353 A	6/1997	Roy, III et al.	5,790,541 A	8/1998	Patrick et al.
5,646,986 A	7/1997	Sahni et al.	5,790,935 A	8/1998	Payton
5,646,988 A	7/1997	Hikawa	5,793,846 A	8/1998	Katz
5,649,287 A	7/1997	Forssen et al.	5,793,868 A	8/1998	Micali
5,652,788 A	7/1997	Hara	5,796,791 A	8/1998	Polcyn
5,655,013 A	8/1997	Gainsboro	5,796,816 A	8/1998	Utsumi
5,655,014 A	8/1997	Walsh et al.	5,799,077 A	8/1998	Yoshii
5,657,074 A	8/1997	Ishibe et al.	5,799,087 A	8/1998	Rosen
5,661,283 A	8/1997	Gallacher et al.	5,802,503 A	9/1998	Sansone
5,663,891 A	9/1997	Bamji et al.	5,806,071 A	9/1998	Balderrama et al.
5,664,006 A	9/1997	Monte et al.	5,809,019 A	9/1998	Ichihara et al.
5,666,416 A	9/1997	Micali	5,812,642 A	9/1998	Leroy
5,675,637 A	10/1997	Szlam et al.	5,812,668 A	9/1998	Weber
5,677,955 A	10/1997	Doggett et al.	5,815,551 A	9/1998	Katz
5,679,940 A	10/1997	Templeton et al.	5,815,554 A	9/1998	Burgess et al.
5,684,863 A	11/1997	Katz	5,815,566 A	9/1998	Ramot et al.
5,684,997 A	11/1997	Kau et al.	5,815,657 A	9/1998	Williams et al.
5,687,225 A	11/1997	Jorgensen	5,822,400 A	10/1998	Smith
5,691,727 A	11/1997	Cyzs	5,822,401 A	10/1998	Cave et al.
5,692,033 A	11/1997	Farris	5,822,410 A	10/1998	McCausland et al.
5,692,034 A	11/1997	Richardson, Jr. et al.	5,822,550 A	10/1998	Milhaupt et al.
5,696,809 A	12/1997	Voit	5,825,869 A	10/1998	Brooks et al.
5,696,818 A	12/1997	Doremus et al.	5,828,731 A	10/1998	Szlam et al.
5,696,908 A	12/1997	Muehlberger et al.	5,828,734 A	10/1998	Katz
5,697,056 A	12/1997	Tayloe	5,828,840 A	10/1998	Cowan et al.
5,699,418 A	12/1997	Jones	5,832,089 A	11/1998	Kravitz et al.
5,701,295 A	12/1997	Bales et al.	5,835,572 A	11/1998	Richardson, Jr. et al.
5,703,935 A	12/1997	Raissyen et al.	5,835,733 A	11/1998	Walsh et al.
5,710,911 A	1/1998	Walsh et al.	5,835,896 A	11/1998	Fisher et al.
5,713,075 A	1/1998	Threadgill et al.	5,838,663 A	11/1998	Elwalid et al.
5,715,307 A	2/1998	Zazzera	5,838,772 A	11/1998	Wilson et al.
5,717,741 A	2/1998	Yue et al.	5,838,779 A	11/1998	Fuller et al.
5,717,757 A	2/1998	Micali	5,839,119 A	11/1998	Krsul et al.
5,719,861 A	2/1998	Okanoue	5,841,758 A	11/1998	Chen et al.
5,721,916 A	2/1998	Pardikar	5,841,852 A	11/1998	He
5,721,933 A	2/1998	Walsh et al.	5,842,005 A	11/1998	Walsh et al.
RE35,758 E	3/1998	Winter et al.	5,844,900 A	12/1998	Hong et al.
			5,845,132 A	12/1998	Walsh et al.
			5,848,143 A	12/1998	Andrews et al.
			5,848,253 A	12/1998	Walsh et al.
			5,848,266 A	12/1998	Scheurich

US 10,491,748 B1

(56)	References Cited					
	U.S. PATENT DOCUMENTS					
	5,850,385	A	12/1998	Esaki	5,924,016	A 7/1999 Fuller et al.
	5,850,428	A	12/1998	Day	5,926,528	A 7/1999 David
	5,850,446	A	12/1998	Berger et al.	5,926,539	A 7/1999 Shtivelman
	5,850,617	A	12/1998	Libby	5,926,548	A 7/1999 Okamoto
	5,852,370	A	12/1998	Ko	5,930,339	A 7/1999 Nepustil
	5,854,832	A	12/1998	Dezonno	5,930,777	A 7/1999 Barber
	5,854,899	A	12/1998	Callon et al.	5,933,480	A 8/1999 Felger
	5,854,903	A	12/1998	Morrison et al.	5,933,492	A 8/1999 Turovski
	5,857,013	A	1/1999	Yue et al.	5,933,498	A 8/1999 Schneck et al.
	5,857,023	A	1/1999	Demers et al.	5,937,042	A 8/1999 Sofman
	5,864,702	A	1/1999	Walsh et al.	5,937,055	A 8/1999 Kaplan
	5,867,386	A	2/1999	Hoffberg et al.	5,937,390	A 8/1999 Hyodo
	5,867,559	A	2/1999	Jorgensen et al.	5,937,394	A 8/1999 Wong et al.
	5,867,564	A	2/1999	Bhusri	5,940,493	A 8/1999 Desai et al.
	5,867,572	A	2/1999	MacDonald et al.	5,940,496	A 8/1999 Gisby et al.
	5,867,717	A	2/1999	Milhaupt et al.	5,940,497	A 8/1999 Miloslaysky
	5,867,799	A	2/1999	Lang et al.	5,940,813	A 8/1999 Hutchings
	5,870,464	A	2/1999	Brewster et al.	5,940,947	A 8/1999 Takeuchi et al.
	5,870,617	A	2/1999	Walsh et al.	5,941,813	A 8/1999 Sievers et al.
	5,870,621	A	2/1999	Walsh et al.	5,943,403	A 8/1999 Richardson, Jr. et al.
	5,870,771	A	2/1999	Oberg	5,943,424	A 8/1999 Berger et al.
	5,872,833	A	2/1999	Scherer	5,943,507	A 8/1999 Cornish et al.
	5,872,918	A	2/1999	Malomsoky et al.	5,946,387	A 8/1999 Miloslaysky
	5,872,983	A	2/1999	Walsh et al.	5,946,388	A 8/1999 Walker et al.
	5,873,071	A	2/1999	Ferstenberg et al.	5,946,394	A 8/1999 Gambuzza
	5,875,108	A	2/1999	Hoffberg et al.	5,946,669	A 8/1999 Polk
	5,875,312	A	2/1999	Walsh et al.	5,949,045	A 9/1999 Ezawa et al.
	5,878,126	A	3/1999	Velamuri et al.	5,949,852	A 9/1999 Duncan
	5,878,130	A	3/1999	Andrews et al.	5,949,854	A 9/1999 Sato
	5,880,958	A	3/1999	Helms et al.	5,949,863	A 9/1999 Tansky
	5,881,048	A	3/1999	Croslin	5,952,638	A 9/1999 Demers et al.
	5,884,142	A	3/1999	Wiedeman et al.	5,953,229	A 9/1999 Clark et al.
	5,884,277	A	3/1999	Khosla	5,953,332	A 9/1999 Miloslaysky
	5,886,988	A	3/1999	Yun et al.	5,953,338	A 9/1999 Ma et al.
	5,889,505	A	3/1999	Toyama et al.	5,953,405	A 9/1999 Miloslaysky
	5,889,862	A	3/1999	Ohta et al.	5,956,392	A 9/1999 Tanigawa et al.
	5,889,863	A	3/1999	Weber	5,956,397	A 9/1999 Shaffer et al.
	5,890,138	A	3/1999	Godin et al.	5,960,073	A 9/1999 Kikinis et al.
	5,893,902	A	4/1999	Transue et al.	5,960,083	A 9/1999 Micali
	5,894,505	A	4/1999	Koyama	5,963,632	A 10/1999 Miloslaysky
	5,896,446	A	4/1999	Sagady et al.	5,963,635	A 10/1999 Szlam et al.
	5,898,154	A	4/1999	Rosen	5,963,648	A 10/1999 Rosen
	5,898,759	A	4/1999	Huang	5,963,924	A 10/1999 Williams et al.
	5,898,762	A	4/1999	Katz	5,966,094	A 10/1999 Ward et al.
	5,901,209	A	5/1999	Tannenbaum et al.	5,966,310	A 10/1999 Maeda et al.
	5,901,214	A	5/1999	Shaffer et al.	5,966,429	A 10/1999 Scherer
	5,901,229	A	5/1999	Fujisaki et al.	5,970,132	A 10/1999 Brady
	5,901,246	A	5/1999	Hoffberg et al.	5,970,134	A 10/1999 Highland et al.
	5,903,454	A	5/1999	Hoffberg et al.	5,974,120	A 10/1999 Katz
	5,903,641	A *	5/1999	Tonisson H04M 3/5233	5,974,135	A 10/1999 Breneman et al.
				379/265.12	RE36,416	E 11/1999 Szlam et al.
	5,903,651	A	5/1999	Kocher	5,978,465	A 11/1999 Corduroy et al.
	5,903,880	A	5/1999	Biffar	5,978,467	A 11/1999 Walker et al.
	5,905,721	A	5/1999	Liu et al.	5,978,471	A 11/1999 Bokinge
	5,905,792	A	5/1999	Miloslaysky	5,978,840	A 11/1999 Nguyen et al.
	5,905,975	A	5/1999	Ausubel	5,982,352	A 11/1999 Pryor
	5,905,979	A	5/1999	Barrows	5,982,857	A 11/1999 Brady
	5,907,601	A	5/1999	David et al.	5,982,868	A 11/1999 Shaffer et al.
	5,907,608	A	5/1999	Shaffer et al.	5,983,208	A 11/1999 Haller et al.
	5,910,982	A	6/1999	Shaffer et al.	5,983,214	A 11/1999 Lang et al.
	5,912,947	A	6/1999	Langsenkamp et al.	5,987,011	A 11/1999 Toh
	5,913,195	A	6/1999	Weeren et al.	5,987,115	A 11/1999 Petrunka et al.
	5,913,727	A	6/1999	Ahdoot	5,987,116	A 11/1999 Petrunka et al.
	5,914,951	A	6/1999	Bentley et al.	5,987,118	A 11/1999 Dickerman et al.
	5,915,011	A	6/1999	Miloslaysky	5,987,132	A 11/1999 Rowney
	5,915,093	A	6/1999	Berlin et al.	5,987,140	A 11/1999 Rowney et al.
	5,917,893	A	6/1999	Katz	5,987,244	A 11/1999 Kau et al.
	5,917,903	A	6/1999	Jolissaint	5,987,328	A 11/1999 Ephremides et al.
	5,918,021	A	6/1999	Aditya	5,991,391	A 11/1999 Miloslaysky
	5,918,213	A	6/1999	Bernard et al.	5,991,392	A 11/1999 Miloslaysky
	5,920,477	A	7/1999	Hoffberg et al.	5,991,393	A 11/1999 Kamen
	5,920,629	A	7/1999	Rosen	5,991,395	A 11/1999 Miloslaysky
	5,922,049	A	7/1999	Radia et al.	5,991,604	A 11/1999 Yi
	5,923,745	A	7/1999	Hurd	5,991,761	A 11/1999 Mahoney et al.
	5,923,746	A	7/1999	Baker et al.	5,995,080	A 11/1999 Biro et al.
					5,995,614	A 11/1999 Miloslaysky
					5,995,615	A 11/1999 Miloslaysky
					5,995,948	A 11/1999 Whitford et al.
					5,996,076	A 11/1999 Rowney et al.

US 10,491,748 B1

Page 6

(56)

References Cited

U.S. PATENT DOCUMENTS

5,999,908	A	12/1999	Abelow	6,084,955	A	7/2000	Key et al.
5,999,919	A	12/1999	Jarecki et al.	6,084,979	A	7/2000	Kanade et al.
5,999,965	A	12/1999	Kelly	6,097,369	A	8/2000	Wambach
6,002,760	A	12/1999	Gisby	6,097,771	A	8/2000	Foschini
6,002,767	A	12/1999	Kramer	6,097,806	A	8/2000	Baker et al.
6,003,765	A	12/1999	Okamoto	6,098,069	A	8/2000	Yamaguchi
6,005,534	A	12/1999	Hylin et al.	6,101,180	A	8/2000	Donahue et al.
6,005,928	A	12/1999	Johnson	6,102,970	A	8/2000	Kneipp
6,005,931	A	12/1999	Neyman et al.	6,104,801	A	8/2000	Miloslaysky
6,005,939	A	12/1999	Fortenberry et al.	6,112,181	A	8/2000	Shear et al.
6,006,218	A	12/1999	Breese et al.	6,112,186	A	8/2000	Bergh et al.
6,009,149	A	12/1999	Langsenkamp	6,112,273	A	8/2000	Kau et al.
6,011,845	A	1/2000	Nabkel et al.	6,115,462	A	9/2000	Servi et al.
6,014,439	A	1/2000	Walker et al.	6,115,693	A	9/2000	McDonough et al.
6,016,307	A	1/2000	Kaplan et al.	6,118,865	A	9/2000	Gisby
6,016,344	A	1/2000	Katz	6,122,291	A	9/2000	Robinson et al.
6,016,475	A	1/2000	Miller et al.	6,122,358	A	9/2000	Shoji et al.
6,016,484	A	1/2000	Williams et al.	6,122,360	A	9/2000	Neyman et al.
6,018,579	A	1/2000	Petrunka	6,122,364	A	9/2000	Petrunka et al.
6,018,659	A	1/2000	Ayyagari et al.	6,122,484	A	9/2000	Fuller et al.
6,018,724	A	1/2000	Arent	6,125,178	A	9/2000	Walker et al.
6,018,738	A	1/2000	Breese et al.	6,128,376	A	10/2000	Smith
6,021,114	A	2/2000	Shaffer et al.	6,128,380	A	10/2000	Shaffer et al.
6,021,190	A	2/2000	Fuller et al.	6,130,937	A	10/2000	Fotta
6,021,202	A	2/2000	Anderson et al.	6,134,235	A	10/2000	Goldman et al.
6,021,399	A	2/2000	Demers et al.	6,134,530	A	10/2000	Bunting et al.
6,021,428	A	2/2000	Miloslaysky	6,137,862	A	10/2000	Atkinson et al.
6,026,149	A	2/2000	Fuller et al.	6,137,870	A	10/2000	Scherer
6,026,156	A	2/2000	Epler et al.	6,138,119	A	10/2000	Hall et al.
6,026,379	A	2/2000	Haller et al.	6,141,325	A	10/2000	Gerstel
6,029,150	A	2/2000	Kravitz	6,144,711	A	11/2000	Raleigh et al.
6,029,151	A	2/2000	Nikander	6,144,737	A	11/2000	Maruyama et al.
6,029,161	A	2/2000	Lang et al.	6,144,964	A	11/2000	Breese et al.
6,031,899	A	2/2000	Wu	6,146,026	A	11/2000	Ushiku
6,035,021	A	3/2000	Katz	6,147,975	A	11/2000	Bowman-Amuah
6,035,402	A	3/2000	Vaeth et al.	6,148,065	A	11/2000	Katz
6,041,116	A	3/2000	Meyers	6,151,387	A	11/2000	Katz
6,041,118	A	3/2000	Michel et al.	6,154,528	A	11/2000	Bennett, III et al.
6,044,135	A	3/2000	Katz	6,154,535	A	11/2000	Velamuri et al.
6,044,146	A	3/2000	Gisby et al.	RE37,001	E	12/2000	Morganstein et al.
6,044,149	A	3/2000	Shaham et al.	6,157,655	A	12/2000	Shtivelman
6,044,355	A	3/2000	Crockett et al.	6,157,711	A	12/2000	Katz
6,044,368	A	3/2000	Powers	6,163,607	A *	12/2000	Bogart H04M 3/5233 379/265.02
6,047,067	A	4/2000	Rosen	6,170,011	B1	1/2001	Macleod Beck et al.
6,047,269	A	4/2000	Biffar	6,170,742	B1	1/2001	Yacooob
6,047,887	A	4/2000	Rosen	6,173,052	B1	1/2001	Brady
6,049,327	A	4/2000	Walker et al.	6,173,053	B1	1/2001	Bogart et al.
6,049,599	A	4/2000	McCausland et al.	6,175,563	B1	1/2001	Miloslaysky
6,049,786	A	4/2000	Smorodinsky	6,175,564	B1	1/2001	Miloslaysky et al.
6,049,787	A	4/2000	Takahashi et al.	6,177,932	B1	1/2001	Galdes et al.
6,052,453	A	4/2000	Sagady et al.	6,178,240	B1	1/2001	Walker et al.
6,055,307	A	4/2000	Behnke et al.	6,185,283	B1	2/2001	Fuller et al.
6,055,508	A	4/2000	Naor et al.	6,185,292	B1	2/2001	Miloslaysky
6,055,571	A	4/2000	Fulp et al.	6,185,598	B1	2/2001	Farber et al.
6,057,872	A	5/2000	Candelore	6,185,683	B1	2/2001	Ginter et al.
6,058,381	A	5/2000	Nelson	6,192,121	B1	2/2001	Atkinson et al.
6,058,435	A *	5/2000	Sassin H04M 3/51 379/265.12	6,192,413	B1	2/2001	Lee et al.
6,061,347	A	5/2000	Hollatz et al.	6,198,487	B1	3/2001	Fortenbery et al.
6,061,448	A	5/2000	Smith et al.	6,201,950	B1	3/2001	Fuller et al.
6,061,665	A	5/2000	Bahreman	6,205,207	B1	3/2001	Scherer
6,064,667	A	5/2000	Gisby et al.	6,208,970	B1	3/2001	Ramanan
6,064,730	A	5/2000	Ginsberg	6,212,178	B1	4/2001	Beck et al.
6,064,731	A	5/2000	Flockhart et al.	6,215,263	B1	4/2001	Berkowitz et al.
6,064,973	A	5/2000	Smith et al.	6,223,165	B1	4/2001	Lauffer
6,065,675	A	5/2000	Teicher	6,226,287	B1	5/2001	Brady
6,067,348	A	5/2000	Hibbeler	6,226,289	B1	5/2001	Williams et al.
6,069,894	A	5/2000	Holender et al.	6,226,360	B1	5/2001	Goldberg et al.
6,070,142	A	5/2000	McDonough et al.	6,229,888	B1	5/2001	Miloslaysky
6,072,864	A	6/2000	Shtivelman et al.	6,230,197	B1	5/2001	Beck et al.
6,072,870	A	6/2000	Nguyen et al.	6,230,203	B1	5/2001	Koperda et al.
6,078,928	A	6/2000	Schnase et al.	6,233,332	B1	5/2001	Anderson et al.
6,081,750	A	6/2000	Hoffberg et al.	6,236,978	B1	5/2001	Tuzhilin
6,084,864	A	7/2000	Liron	6,236,980	B1	5/2001	Reese
6,084,943	A	7/2000	Sunderman et al.	6,243,684	B1	6/2001	Stuart et al.
				6,249,241	B1	6/2001	Jordan et al.
				6,253,080	B1	6/2001	Wiedeman et al.
				6,253,193	B1	6/2001	Ginter et al.
				6,253,313	B1	6/2001	Morrison et al.

US 10,491,748 B1

Page 7

(56)

References Cited

U.S. PATENT DOCUMENTS

6,256,648 B1	7/2001	Hill et al.	6,691,173 B2	2/2004	Morris et al.
6,266,649 B1	7/2001	Linden et al.	6,697,858 B1	2/2004	Ezerzer et al.
6,272,483 B1	8/2001	Joslin et al.	6,720,949 B1	4/2004	Pryor et al.
6,275,470 B1	8/2001	Ricciulli	6,728,113 B1	4/2004	Knight et al.
6,304,556 B1	10/2001	Haas	6,735,440 B2	5/2004	Wiedeman et al.
6,304,639 B1	10/2001	Malomsoky et al.	6,735,630 B1	5/2004	Gelvin et al.
6,308,175 B1	10/2001	Lang et al.	6,737,958 B1	5/2004	Satyanarayana
6,314,420 B1	11/2001	Lang et al.	6,757,268 B1	6/2004	Zendle
6,317,718 B1	11/2001	Fano	6,778,502 B2	8/2004	Ricciulli
6,317,722 B1	11/2001	Jacobi et al.	6,826,549 B1	11/2004	Marks et al.
6,321,179 B1	11/2001	Glance et al.	6,826,607 B1	11/2004	Gelvin et al.
6,321,221 B1	11/2001	Bieganski	6,832,251 B1	12/2004	Gelvin et al.
6,327,590 B1	12/2001	Chidlovskii et al.	6,859,831 B1	2/2005	Gelvin et al.
6,331,986 B1	12/2001	Mitra et al.	6,865,170 B1	3/2005	Zendle
6,333,979 B1	12/2001	Bondi et al.	6,888,899 B2	5/2005	Raleigh et al.
6,333,980 B1	12/2001	Hollatz et al.	6,898,205 B1	5/2005	Chaskar et al.
6,334,127 B1	12/2001	Bieganski et al.	6,904,421 B2	6/2005	Shetty
6,334,131 B2	12/2001	Chakrabarti et al.	6,916,719 B1	7/2005	Knight et al.
6,345,264 B1	2/2002	Breese et al.	6,938,099 B2	8/2005	Morton et al.
6,347,139 B1	2/2002	Fisher et al.	6,975,613 B1	12/2005	Johansson
6,353,813 B1	3/2002	Breese et al.	6,981,055 B1	12/2005	Ahuja et al.
6,356,899 B1	3/2002	Chakrabarti et al.	7,020,086 B2	3/2006	Juttner et al.
6,363,334 B1	3/2002	Andrews et al.	7,020,701 B1	3/2006	Gelvin et al.
6,374,227 B1	4/2002	Ye	7,023,979 B1	4/2006	Wu et al.
6,377,631 B1	4/2002	Raleigh	7,042,440 B2	5/2006	Pryor et al.
6,377,805 B1	4/2002	Anvekar et al.	7,054,850 B2	5/2006	Matsugu
6,389,372 B1	5/2002	Glance et al.	7,058,296 B2	6/2006	Sanjee et al.
6,400,996 B1	6/2002	Hoffberg et al.	7,070,110 B2	7/2006	Lapstun et al.
6,405,922 B1	6/2002	Kroll	7,075,892 B2	7/2006	Grover et al.
6,411,603 B1	6/2002	Ahuja et al.	7,079,529 B1	7/2006	Khuc
6,412,012 B1	6/2002	Bieganski et al.	7,085,249 B2	8/2006	Lohtia et al.
6,418,148 B1	7/2002	Kumar et al.	7,097,106 B2	8/2006	Silverbrook et al.
6,418,424 B1	7/2002	Hoffberg et al.	7,110,525 B1	9/2006	Heller et al.
6,421,709 B1	7/2002	McCormick et al.	7,128,265 B2	10/2006	Silverbrook et al.
6,421,754 B1	7/2002	Kau et al.	7,128,270 B2	10/2006	Silverbrook et al.
6,430,558 B1	8/2002	Delano	7,131,596 B2	11/2006	Lapstun et al.
6,446,035 B1	9/2002	Grefenstette et al.	7,136,448 B1	11/2006	Venkataperumal et al.
6,449,367 B2	9/2002	Van Wie et al.	7,137,566 B2	11/2006	Silverbrook et al.
6,452,981 B1	9/2002	Raleigh et al.	7,145,971 B2	12/2006	Raleigh et al.
6,453,038 B1	9/2002	McFarlane et al.	7,150,398 B2	12/2006	Silverbrook et al.
6,456,025 B2	9/2002	Berkowitz et al.	7,159,777 B2	1/2007	Silverbrook et al.
6,459,784 B1	10/2002	Humphrey et al.	7,175,089 B2	2/2007	Silverbrook et al.
6,463,299 B1	10/2002	Macor	7,178,719 B2	2/2007	Silverbrook et al.
6,466,654 B1	10/2002	Cooper et al.	7,188,769 B2	3/2007	Silverbrook et al.
6,466,909 B1	10/2002	Didcock	7,197,374 B2	3/2007	Silverbrook et al.
6,466,970 B1	10/2002	Lee et al.	7,203,249 B2	4/2007	Raleigh et al.
6,470,077 B1	10/2002	Chan	7,207,483 B2	4/2007	Silverbrook et al.
6,473,405 B2	10/2002	Ricciulli	7,207,485 B2	4/2007	Silverbrook et al.
6,477,245 B1	11/2002	Chevet et al.	7,221,287 B2	5/2007	Guezic et al.
6,477,246 B1	11/2002	Dolan et al.	7,243,849 B2	7/2007	Lapstun et al.
6,477,494 B2	11/2002	Hyde-Thomson et al.	7,267,273 B2	9/2007	Silverbrook et al.
6,480,844 B1	11/2002	Cortes et al.	7,269,253 B1	9/2007	Wu et al.
6,484,123 B2	11/2002	Srivastava	7,270,266 B2	9/2007	Silverbrook et al.
6,487,289 B1	11/2002	Phan et al.	7,295,568 B2	11/2007	Kossi et al.
6,487,533 B2	11/2002	Hyde-Thomson et al.	7,296,737 B2	11/2007	Silverbrook et al.
6,493,432 B1	12/2002	Blum et al.	7,314,177 B2	1/2008	Lapstun et al.
6,493,696 B1	12/2002	Chazin	7,314,181 B2	1/2008	Lapstun et al.
6,496,568 B1	12/2002	Nelson	7,346,865 B2	3/2008	Su et al.
6,510,221 B1	1/2003	Fisher et al.	7,356,224 B2	4/2008	Levner et al.
6,519,259 B1	2/2003	Baker et al.	7,357,323 B2	4/2008	Silverbrook et al.
6,519,459 B1	2/2003	Chavez, Jr. et al.	7,358,929 B2	4/2008	Mueller et al.
6,522,726 B1	2/2003	Hunt et al.	7,365,674 B2	4/2008	Tillotson et al.
6,529,870 B1	3/2003	Mikkilineni	7,372,952 B1	5/2008	Wu et al.
6,529,891 B1	3/2003	Heckerman	7,375,649 B2	5/2008	Guezic
6,536,935 B2	3/2003	Parunak et al.	7,383,984 B2	6/2008	Silverbrook et al.
6,553,114 B1	4/2003	Fisher et al.	7,383,991 B2	6/2008	Silverbrook et al.
6,553,355 B1	4/2003	Arnoux et al.	7,400,903 B2	7/2008	Shoemake et al.
6,577,600 B1	6/2003	Bare	7,421,678 B2	9/2008	Barnes et al.
6,577,613 B1	6/2003	Ramanathan	7,441,225 B2	10/2008	Boutin et al.
6,636,840 B1	10/2003	Goray et al.	7,450,273 B2	11/2008	Silverbrook et al.
6,650,655 B2	11/2003	Alvesalo et al.	7,451,449 B2	11/2008	Thompson et al.
6,650,871 B1	11/2003	Cannon et al.	7,457,007 B2	11/2008	Silverbrook et al.
6,661,889 B1 *	12/2003	Flockhart H04M 3/5232 379/265.05	7,463,726 B2	12/2008	Jensen et al.
6,678,252 B1	1/2004	Cansever	7,464,156 B2	12/2008	Amir et al.
			7,466,913 B2	12/2008	Sanjee et al.
			7,469,836 B2	12/2008	Silverbrook et al.
			7,480,248 B2	1/2009	Duggi et al.
			7,496,257 B2	2/2009	Levner et al.
			7,506,808 B2	3/2009	Silverbrook et al.

US 10,491,748 B1

Page 8

(56)

References Cited

U.S. PATENT DOCUMENTS

7,508,321	B2	3/2009	Gueziec et al.	8,023,425	B2	9/2011	Raleigh
7,537,160	B2	5/2009	Silverbrook et al.	8,036,307	B2	10/2011	Raleigh et al.
7,542,426	B1	6/2009	Connors et al.	8,041,163	B2	10/2011	Levner et al.
7,555,060	B2	6/2009	Raleigh et al.	8,046,319	B2	10/2011	Satir et al.
7,555,542	B1	6/2009	Ayers et al.	8,054,965	B1	11/2011	Wu et al.
7,557,730	B2	7/2009	Gueziec	8,060,017	B2	11/2011	Schlicht et al.
7,561,532	B2	7/2009	Bossi et al.	8,068,095	B2	11/2011	Pryor
7,566,009	B2	7/2009	Lapstun et al.	8,079,517	B2	12/2011	Silverbrook et al.
7,568,629	B2	8/2009	Lapstun et al.	8,090,530	B2	1/2012	Horvitz
7,590,589	B2	9/2009	Hoffberg	8,103,797	B2	1/2012	Day
7,605,940	B2	10/2009	Silverbrook et al.	8,111,239	B2	2/2012	Pryor et al.
7,609,614	B2	10/2009	Fonseka et al.	8,112,300	B2	2/2012	Harper
7,610,151	B2	10/2009	Letchner et al.	8,122,392	B2	2/2012	White et al.
7,612,923	B2	11/2009	Rusman et al.	8,130,758	B2	3/2012	Cohen
7,617,976	B2	11/2009	Silverbrook et al.	8,132,729	B2	3/2012	Silverbrook et al.
7,624,337	B2	11/2009	Sull et al.	8,140,658	B1	3/2012	Gelvin et al.
7,630,948	B2	12/2009	Friedlander et al.	8,144,619	B2	3/2012	Hoffberg
7,637,437	B2	12/2009	Lapstun et al.	8,149,707	B2	4/2012	Steer et al.
7,647,286	B2	1/2010	Friedlander et al.	8,205,179	B2	6/2012	Su et al.
7,647,288	B2	1/2010	Friedlander et al.	8,205,185	B2	6/2012	Su et al.
7,648,068	B2	1/2010	Silverbrook et al.	8,212,688	B2	7/2012	Morioka et al.
7,653,609	B2	1/2010	Friedlander et al.	8,223,726	B2	7/2012	Zendle
7,653,884	B2	1/2010	Furnish et al.	8,225,319	B2	7/2012	Laithwaite et al.
7,654,454	B2	2/2010	Silverbrook et al.	8,228,839	B2	7/2012	Fonseka et al.
7,664,188	B2	2/2010	Raleigh et al.	8,229,812	B2	7/2012	Raleigh
7,669,160	B2	2/2010	Furnish et al.	8,229,834	B2	7/2012	Borkovec et al.
7,676,034	B1	3/2010	Wu et al.	8,238,541	B1 *	8/2012	Kalavar H04M 3/5233
7,688,807	B2	3/2010	Yegoshin				379/265.06
7,698,246	B2	4/2010	Friedlander et al.	8,250,207	B2	8/2012	Raleigh
7,702,187	B2	4/2010	Rusman et al.	8,260,652	B1	9/2012	Silver et al.
7,721,961	B2	5/2010	Silverbrook et al.	8,270,310	B2	9/2012	Raleigh
7,734,783	B1 *	6/2010	Bourke H04M 3/51	8,270,952	B2	9/2012	Raleigh
			379/265.01	8,284,461	B2	10/2012	Rusman et al.
7,739,040	B2	6/2010	Horvitz	8,285,681	B2	10/2012	Prahlad et al.
7,752,150	B2	7/2010	Ye et al.	8,296,221	B1	10/2012	Waelbroeck et al.
7,752,588	B2	7/2010	Bose	8,300,798	B1	10/2012	Wu et al.
7,756,008	B2	7/2010	Bellovin	8,311,377	B2	11/2012	Levner et al.
7,773,740	B2 *	8/2010	Beckstrom H04M 3/5235	8,321,526	B2	11/2012	Raleigh
			370/352	8,322,612	B2	12/2012	Silverbrook et al.
7,797,367	B1	9/2010	Gelvin et al.	8,323,189	B2	12/2012	Tran et al.
7,801,490	B1	9/2010	Scherzer	8,326,958	B1	12/2012	Raleigh
7,814,451	B2	10/2010	Furnish et al.	8,331,901	B2	12/2012	Raleigh
7,817,796	B1	10/2010	Clippinger et al.	8,332,247	B1	12/2012	Bailey et al.
7,819,323	B2	10/2010	Silverbrook et al.	8,332,793	B2	12/2012	Bose
7,823,055	B2	10/2010	Sull et al.	8,335,704	B2	12/2012	Treffer et al.
7,826,560	B2	11/2010	Raleigh et al.	8,347,243	B2	1/2013	Bruneel
7,840,133	B2	11/2010	Zaacks et al.	8,351,898	B2	1/2013	Raleigh
7,843,429	B2	11/2010	Pryor	8,352,587	B2	1/2013	Day
7,844,687	B1	11/2010	Gelvin et al.	8,355,337	B2	1/2013	Raleigh
7,852,786	B2	12/2010	Wang et al.	8,358,222	B2	1/2013	Gueziec
7,869,221	B2	1/2011	Knight et al.	8,364,515	B1	1/2013	Procopiuc
7,874,481	B2	1/2011	Silverbrook et al.	8,385,916	B2	2/2013	Raleigh
7,877,304	B1	1/2011	Coulter	8,396,458	B2	3/2013	Raleigh
7,878,408	B2	2/2011	Lapstun et al.	8,405,604	B2	3/2013	Pryor et al.
7,878,416	B2	2/2011	Lapstun et al.	8,406,733	B2	3/2013	Raleigh
7,880,642	B2	2/2011	Gueziec	8,407,190	B2	3/2013	Prahlad et al.
7,890,857	B1	2/2011	Jouppi	8,411,842	B1	4/2013	Wu et al.
7,894,595	B1	2/2011	Wu et al.	8,416,468	B2	4/2013	Underwood et al.
7,900,841	B2	3/2011	Lapstun et al.	8,433,645	B1	4/2013	Waelbroeck et al.
7,907,517	B2	3/2011	Steven	8,437,271	B2	5/2013	Raleigh
7,912,791	B2	3/2011	Boutin et al.	8,441,989	B2	5/2013	Raleigh
7,916,858	B1	3/2011	Heller et al.	8,442,030	B2	5/2013	Dennison
7,918,399	B2	4/2011	Silverbrook et al.	8,442,152	B2	5/2013	Raleigh et al.
7,921,392	B2	4/2011	Furnish et al.	8,447,231	B2	5/2013	Bai et al.
7,921,393	B2	4/2011	Furnish et al.	8,467,312	B2	6/2013	Raleigh
7,934,650	B2	5/2011	Silverbrook et al.	8,473,197	B2	6/2013	Horvitz
7,946,485	B2	5/2011	Silverbrook et al.	8,475,368	B2	7/2013	Tran et al.
7,953,888	B2	5/2011	Ricciulli	8,478,667	B2	7/2013	Raleigh
7,961,360	B2	6/2011	Rusman et al.	8,479,157	B2	7/2013	Treffer et al.
7,962,873	B2	6/2011	Su et al.	8,509,032	B2	8/2013	Rakib
7,962,882	B2	6/2011	Su et al.	8,516,552	B2	8/2013	Raleigh
8,000,988	B1	8/2011	Bezanson et al.	8,531,312	B2	9/2013	Gueziec
8,005,111	B2	8/2011	Lauther	8,531,986	B2	9/2013	Raleigh
8,005,654	B2	8/2011	Boldyrev et al.	8,532,209	B2	9/2013	Fonseka et al.
8,022,943	B2	9/2011	Silverbrook et al.	8,537,033	B2	9/2013	Gueziec
				8,547,872	B2	10/2013	Raleigh
				8,554,458	B2	10/2013	Sawhill et al.
				8,564,455	B2	10/2013	Gueziec
				8,566,447	B2	10/2013	Cohen et al.

US 10,491,748 B1

Page 9

(56)

References Cited

U.S. PATENT DOCUMENTS

8,570,908 B2	10/2013	Raleigh	8,839,388 B2	9/2014	Raleigh
8,578,348 B2	11/2013	Fliess et al.	8,847,887 B2	9/2014	Pryor
8,583,781 B2	11/2013	Raleigh	8,849,761 B2	9/2014	Prahlad et al.
8,588,110 B2	11/2013	Raleigh	8,849,860 B2	9/2014	Ilyas et al.
8,594,917 B2	11/2013	Sawhill et al.	8,849,955 B2	9/2014	Prahlad et al.
8,599,697 B2	12/2013	Ricciulli	8,856,846 B2	10/2014	Applegate et al.
8,600,830 B2	12/2013	Hoffberg	8,862,386 B2	10/2014	Griffiths
8,612,107 B2	12/2013	Malikopoulos	8,874,477 B2	10/2014	Hoffberg
8,612,439 B2	12/2013	Prahlad et al.	8,879,715 B2	11/2014	Spottiswoode et al.
8,614,668 B2	12/2013	Pryor	8,886,162 B2	11/2014	Raleigh
8,626,540 B2	1/2014	Peterkofsky et al.	8,897,743 B2	11/2014	Raleigh
8,630,192 B2	1/2014	Raleigh	8,897,744 B2	11/2014	Raleigh
8,630,284 B2	1/2014	Yegoshin	8,898,079 B2	11/2014	Raleigh
8,630,611 B2	1/2014	Raleigh	8,898,232 B2	11/2014	Magharei et al.
8,631,102 B2	1/2014	Raleigh	8,898,617 B2	11/2014	White et al.
8,635,147 B2	1/2014	Borkovec et al.	8,903,079 B2	12/2014	Xie et al.
8,635,678 B2	1/2014	Raleigh	8,903,452 B2	12/2014	Raleigh
8,639,811 B2	1/2014	Raleigh	8,913,590 B2	12/2014	Fantini et al.
8,639,935 B2	1/2014	Raleigh	8,922,829 B2	12/2014	Fu et al.
8,640,198 B2	1/2014	Raleigh	8,924,269 B2	12/2014	Seubert et al.
8,650,432 B2	2/2014	Nakata	8,924,527 B2	12/2014	Ramankutty et al.
8,652,038 B2	2/2014	Tran et al.	8,924,549 B2	12/2014	Raleigh
8,666,364 B2	3/2014	Raleigh	8,929,537 B2	1/2015	Chishti et al.
8,667,571 B2	3/2014	Raleigh	8,929,877 B2	1/2015	Rhoads et al.
8,670,548 B2	3/2014	Xie et al.	8,954,262 B2	2/2015	Sawhill et al.
8,675,507 B2	3/2014	Raleigh	8,958,988 B2	2/2015	Gueziec
8,688,099 B2	4/2014	Raleigh	8,959,480 B2	2/2015	Trefler et al.
8,695,073 B2	4/2014	Raleigh	8,965,587 B2	2/2015	Modi et al.
8,699,674 B2	4/2014	Bouzid et al.	8,965,672 B2	2/2015	Sawhill et al.
8,699,694 B2	4/2014	Chishti et al.	8,977,619 B2	3/2015	Mann et al.
8,700,548 B2	4/2014	Bhandari et al.	8,983,874 B2	3/2015	Micali et al.
8,706,120 B2	4/2014	Hwang et al.	8,990,740 B2	3/2015	Zhang et al.
8,706,914 B2	4/2014	Duchesneau	9,003,346 B1	4/2015	Dutta et al.
8,706,915 B2	4/2014	Duchesneau	9,008,960 B2	4/2015	Horvitz
8,713,630 B2	4/2014	Raleigh	9,009,056 B2	4/2015	Markefka et al.
8,718,271 B2	5/2014	Spottiswoode	9,009,318 B2	4/2015	Rangarajan et al.
8,718,925 B2	5/2014	Letchner et al.	9,014,026 B2	4/2015	Raleigh
8,724,554 B2	5/2014	Raleigh	9,020,137 B2	4/2015	Chishti et al.
8,724,797 B2	5/2014	Chishti et al.	9,025,757 B2	5/2015	Spottiswoode et al.
8,727,978 B2	5/2014	Tran et al.	9,037,127 B2	5/2015	Raleigh
8,731,178 B2	5/2014	Chishti et al.	9,046,379 B2	6/2015	Mineta
8,736,548 B2	5/2014	Pryor	9,070,291 B2	6/2015	Gueziec
8,737,595 B2	5/2014	Chishti et al.	9,071,547 B2	6/2015	McCord et al.
8,737,957 B2	5/2014	Raleigh	9,082,303 B2	7/2015	Gueziec
8,743,291 B2	6/2014	Li et al.	9,094,416 B2	7/2015	Magharei et al.
8,744,937 B2	6/2014	Seubert et al.	9,112,534 B2	8/2015	Fonseka et al.
8,745,191 B2	6/2014	Raleigh et al.	9,116,007 B2	8/2015	Griffiths
8,745,220 B2	6/2014	Raleigh et al.	9,118,350 B2	8/2015	Fonseka et al.
8,747,313 B2	6/2014	Tran et al.	9,121,710 B2	9/2015	Gusikhin et al.
8,750,161 B1	6/2014	Matthews et al.	9,122,567 B2	9/2015	MacNeille et al.
8,750,488 B2	6/2014	Spottiswoode et al.	9,131,053 B1	9/2015	Tan et al.
8,755,458 B2	6/2014	Raleigh et al.	9,131,433 B2	9/2015	Steer et al.
8,760,398 B2	6/2014	Pryor	9,137,739 B2	9/2015	Raleigh
8,762,188 B2	6/2014	Abercrombie et al.	9,143,392 B2	9/2015	Duchesneau
8,768,313 B2	7/2014	Rodriguez	9,148,216 B2	9/2015	Spreizer
8,769,077 B2	7/2014	Day	9,157,751 B2	10/2015	Pfeifle
8,775,645 B2	7/2014	Solotorevsky et al.	9,160,405 B1	10/2015	Vareljian et al.
8,781,100 B2	7/2014	Spottiswoode et al.	9,171,008 B2	10/2015	Prahlad et al.
8,781,106 B2	7/2014	Afzal	9,171,151 B2	10/2015	Behrendt et al.
8,782,570 B1	7/2014	Li et al.	9,173,104 B2	10/2015	Raleigh
8,786,464 B2	7/2014	Gueziec	9,177,248 B2	11/2015	Sweeney et al.
8,788,314 B2	7/2014	Procopiuc	9,179,308 B2	11/2015	Raleigh
8,792,630 B2	7/2014	Chishti et al.	9,179,315 B2	11/2015	Raleigh
8,797,908 B2	8/2014	Raleigh	9,179,316 B2	11/2015	Raleigh
8,798,613 B2	8/2014	MacNaughtan et al.	9,184,820 B2	11/2015	Raleigh et al.
8,799,451 B2	8/2014	Raleigh	9,185,232 B2	11/2015	Yegoshin
8,799,830 B2	8/2014	Robles	9,198,117 B2	11/2015	Raleigh
8,805,110 B2	8/2014	Rhoads et al.	9,202,184 B2	12/2015	Friedlander et al.
8,812,654 B2	8/2014	Gelvin et al.	9,204,374 B2	12/2015	Raleigh
8,824,658 B2	9/2014	Chishti	9,212,848 B2	12/2015	Kendall et al.
8,830,873 B2	9/2014	Tomic et al.	9,215,322 B1	12/2015	Wu et al.
8,831,205 B1	9/2014	Wu et al.	9,215,323 B2	12/2015	Chishti
8,832,244 B2	9/2014	Gelvin et al.	9,215,644 B2	12/2015	Kohli
8,836,503 B2	9/2014	Gelvin et al.	9,215,980 B2	12/2015	Tran et al.
8,839,387 B2	9/2014	Raleigh	9,232,403 B2	1/2016	Raleigh
			9,240,808 B2	1/2016	Fonseka et al.
			9,253,663 B2	2/2016	Raleigh et al.
			9,262,734 B2	2/2016	Augenstein et al.
			9,271,133 B2	2/2016	Rodriguez

US 10,491,748 B1

Page 10

(56)

References Cited

U.S. PATENT DOCUMENTS

9,277,055 B2	3/2016	Spottiswoode et al.	9,716,792 B2	7/2017	McGann et al.
9,277,480 B2	3/2016	Kohli	9,721,384 B1	8/2017	Tran et al.
9,288,176 B2	3/2016	Day	9,723,151 B2	8/2017	McGann et al.
9,288,325 B2	3/2016	Chishti et al.	9,723,343 B2	8/2017	Applegate et al.
9,288,326 B2	3/2016	Chishti et al.	9,736,308 B1	8/2017	Wu et al.
9,292,493 B2	3/2016	Chandramouli et al.	9,741,183 B2	8/2017	Matos et al.
9,294,624 B2	3/2016	Williams et al.	9,762,531 B2	9/2017	Day
9,300,802 B1	3/2016	Chishti	9,772,906 B2	9/2017	Lee et al.
9,304,801 B2	4/2016	Koorevaar et al.	9,774,740 B2	9/2017	Chishti
9,307,080 B1	4/2016	Fernandez et al.	9,779,029 B2	10/2017	Frachtenberg et al.
9,311,670 B2	4/2016	Hoffberg	9,780,907 B2	10/2017	Bouda
9,325,282 B2	4/2016	Bowers et al.	9,781,269 B2	10/2017	Chishti et al.
9,336,677 B2	5/2016	Rakib	9,787,372 B2	10/2017	Kohli
9,338,299 B2	5/2016	McCord et al.	9,787,841 B2	10/2017	Chishti et al.
9,351,193 B2	5/2016	Raleigh et al.	9,788,282 B2	10/2017	Neves et al.
9,361,424 B2	6/2016	Robles	9,792,160 B2	10/2017	Shear et al.
9,361,793 B2	6/2016	Curtis et al.	9,794,797 B2	10/2017	Hoffberg
9,368,029 B2	6/2016	Gueziec	9,801,542 B2	10/2017	Tran et al.
9,371,099 B2	6/2016	Lagassey	9,807,239 B1	10/2017	Wu et al.
9,373,960 B2	6/2016	Pande et al.	9,818,136 B1	11/2017	Hoffberg
9,378,065 B2	6/2016	Shear et al.	9,830,827 B2	11/2017	Sawhill et al.
9,386,165 B2	7/2016	Raleigh et al.	9,836,883 B2	12/2017	Tran et al.
9,396,421 B2	7/2016	Rujan	9,857,187 B2	1/2018	Profous et al.
9,401,088 B2	7/2016	Gueziec	9,860,380 B2	1/2018	Shaffer et al.
9,401,992 B2	7/2016	Srinivas et al.	9,860,391 B1	1/2018	Wu et al.
9,406,010 B2	8/2016	Rujan	9,866,698 B2	1/2018	Fernandez et al.
9,413,894 B2	8/2016	Chishti et al.	9,870,629 B2	1/2018	Cardno et al.
9,419,981 B2	8/2016	Stolfo et al.	9,871,924 B1	1/2018	Chishti
9,426,296 B2	8/2016	Chishti et al.	9,886,845 B2	2/2018	Rhoads et al.
9,454,537 B2	9/2016	Prahlad et al.	9,888,120 B1	2/2018	Chishti
9,456,086 B1	9/2016	Wu et al.	9,888,121 B1	2/2018	Chishti
9,460,557 B1	10/2016	Tran et al.	9,904,579 B2	2/2018	Shear et al.
9,460,629 B2	10/2016	Chircop et al.	9,906,647 B2	2/2018	Tendick et al.
9,462,127 B2	10/2016	Kan et al.	9,917,949 B1	3/2018	Chishti
9,468,040 B2	10/2016	Bouzid et al.	9,918,183 B2	3/2018	Rhoads et al.
9,473,221 B2	10/2016	Kohli	9,924,041 B2	3/2018	Kan et al.
9,489,701 B2	11/2016	Emadi et al.	9,930,180 B1	3/2018	Kan et al.
9,489,842 B2	11/2016	Gueziec	9,939,193 B2	4/2018	Kendall et al.
9,491,564 B1	11/2016	Raleigh	9,942,395 B2	4/2018	Lee
9,503,388 B2	11/2016	Ramankutty et al.	9,942,405 B1	4/2018	Kan et al.
9,531,599 B2	12/2016	Prasad et al.	9,946,231 B2	4/2018	Sargolzaei et al.
9,532,161 B2	12/2016	Raleigh	9,948,361 B2	4/2018	Kohli
9,537,545 B2	1/2017	Kohli	9,955,013 B1	4/2018	Chishti
9,557,889 B2	1/2017	Raleigh et al.	9,955,332 B2	4/2018	Raleigh et al.
9,561,860 B2	2/2017	Knapp et al.	9,955,436 B2	4/2018	Neves et al.
9,565,512 B2	2/2017	Rhoads et al.	9,958,288 B2	5/2018	Horvitz et al.
9,565,543 B2	2/2017	Raleigh	9,977,856 B2	5/2018	Robles
9,578,182 B2	2/2017	Raleigh et al.	9,996,810 B2	6/2018	Augenstein et al.
9,581,452 B2	2/2017	Pfeifle	9,996,981 B1	6/2018	Tran et al.
9,602,977 B2	3/2017	Gueziec	RE46,986 E	8/2018	Chishti et al.
9,607,023 B1	3/2017	Swamy	2001/0000458 A1	4/2001	Shtivelman et al.
9,609,459 B2	3/2017	Raleigh	2001/0011228 A1	8/2001	Shenkman
9,615,192 B2	4/2017	Raleigh	2001/0020834 A1	9/2001	Berkowitz et al.
9,615,264 B2	4/2017	Hoffberg	2001/0024497 A1	9/2001	Campbell et al.
9,628,365 B2	4/2017	Gelvin et al.	2001/0034578 A1	10/2001	Ugajin
9,628,879 B2	4/2017	Bouda	2001/0037409 A1	11/2001	Ricciulli
9,635,177 B1	4/2017	Hoffberg	2001/0044788 A1	11/2001	Demir et al.
9,635,181 B1	4/2017	McGann et al.	2002/0006191 A1	1/2002	Weiss
9,640,073 B2	5/2017	Gueziec	2002/0009190 A1	1/2002	McIlwaine et al.
9,641,957 B2	5/2017	Raleigh	2002/0018449 A1	2/2002	Ricciulli
9,645,579 B2	5/2017	Switkes et al.	2002/0019846 A1	2/2002	Miloslavsky et al.
9,654,478 B2	5/2017	Stolfo et al.	2002/0021693 A1	2/2002	Bruno et al.
9,654,633 B2	5/2017	McCord et al.	2002/0032018 A1	3/2002	Morton et al.
9,654,641 B1	5/2017	Chishti et al.	2002/0036617 A1	3/2002	Pryor
9,680,855 B2	6/2017	Schultz et al.	2002/0038233 A1	3/2002	Shubov et al.
9,680,997 B2	6/2017	Chishti et al.	2002/0038294 A1	3/2002	Matsugu
9,686,411 B2	6/2017	Spottiswoode et al.	2002/0039900 A1	4/2002	Wiedeman et al.
9,690,264 B2	6/2017	Hellstrom et al.	2002/0045453 A1	4/2002	Juttner et al.
9,692,490 B2	6/2017	Kohli	2002/0069218 A1	6/2002	Sull et al.
9,692,898 B1	6/2017	Chishti	2002/0087696 A1	7/2002	Byrnes
9,692,899 B1	6/2017	Rizvi	2002/0093942 A1	7/2002	Yegoshin
9,699,314 B2	7/2017	Spottiswoode et al.	2002/0112435 A1	8/2002	Hartman
9,702,349 B2	7/2017	Anderson et al.	2002/0114278 A1	8/2002	Coussement
9,712,676 B1	7/2017	Chishti	2002/0116239 A1	8/2002	Reinsma et al.
9,712,679 B2	7/2017	Chishti et al.	2002/0131399 A1	9/2002	Philonenko
			2002/0133392 A1	9/2002	Angel et al.
			2002/0187770 A1	12/2002	Grover et al.
			2003/0002646 A1	1/2003	Gutta et al.
			2003/0009582 A1	1/2003	Qiao et al.

US 10,491,748 B1

Page 11

(56)

References Cited

U.S. PATENT DOCUMENTS

2003/0014326 A1 1/2003 Ben-Meir et al.
2003/0033237 A1 2/2003 Bawri
2003/0055729 A1 3/2003 Bezos et al.
2003/0055743 A1 3/2003 Murcko
2003/0072382 A1 4/2003 Raleigh et al.
2003/0099343 A1* 5/2003 Dezonno H04M 3/5191
379/265.11

2003/0112784 A1 6/2003 Lohtia et al.
2003/0151513 A1 8/2003 Herrmann et al.
2003/0174651 A1 9/2003 Morton
2003/0195832 A1 10/2003 Cao et al.
2004/0019650 A1 1/2004 Auvenshine
2004/0022194 A1 2/2004 Ricciulli
2004/0046736 A1 3/2004 Pryor et al.
2004/0049479 A1 3/2004 Dorne et al.
2004/0059646 A1 3/2004 Harrington et al.
2004/0081183 A1 4/2004 Monza et al.
2004/0083195 A1 4/2004 McCord et al.
2004/0138958 A1 7/2004 Watarai et al.
2004/0141508 A1 7/2004 Schoeneberger et al.
2004/0156345 A1 8/2004 Steer et al.
2004/0190085 A1 9/2004 Silverbrook et al.
2004/0190092 A1 9/2004 Silverbrook et al.
2004/0195310 A1 10/2004 Silverbrook et al.
2004/0195317 A1 10/2004 Silverbrook et al.
2004/0195318 A1 10/2004 Silverbrook et al.
2004/0195321 A1 10/2004 Silverbrook et al.
2004/0195329 A1 10/2004 Silverbrook et al.
2004/0195330 A1 10/2004 Silverbrook et al.
2004/0195333 A1 10/2004 Silverbrook et al.
2004/0195334 A1 10/2004 Silverbrook et al.
2004/0195336 A1 10/2004 Silverbrook et al.
2004/0195337 A1 10/2004 Silverbrook et al.
2004/0195341 A1 10/2004 Lapstun et al.
2004/0195342 A1 10/2004 Silverbrook et al.
2004/0196501 A1 10/2004 Silverbrook et al.
2004/0199280 A1 10/2004 Silverbrook et al.
2004/0199428 A1 10/2004 Silverbrook et al.
2004/0203815 A1 10/2004 Shoemake et al.
2004/0206824 A1 10/2004 Lapstun et al.
2004/0206827 A1 10/2004 Silverbrook et al.
2004/0210319 A1 10/2004 Lapstun et al.
2004/0212848 A1 10/2004 Lapstun et al.
2004/0213400 A1 10/2004 Golitsin et al.
2004/0232243 A1 11/2004 Silverbrook et al.
2004/0238627 A1 12/2004 Silverbrook et al.
2004/0245332 A1 12/2004 Silverbrook et al.
2004/0252025 A1 12/2004 Silverbrook et al.
2004/0264677 A1 12/2004 Horvitz et al.
2005/0002448 A1 1/2005 Knight et al.
2005/0010571 A1 1/2005 Solotorevsky et al.
2005/0034159 A1 2/2005 Ophir et al.
2005/0041591 A1 2/2005 Duggi et al.
2005/0063004 A1 3/2005 Silverbrook et al.
2005/0065837 A1 3/2005 Kosiba et al.
2005/0071241 A1* 3/2005 Flockhart G06Q 30/0601
705/26.1

2005/0080817 A1 4/2005 Janow
2005/0102221 A1 5/2005 Sulkowski et al.
2005/0116667 A1 6/2005 Mueller et al.
2005/0129217 A1 6/2005 McPartlan et al.
2005/0130701 A1 6/2005 Zendle
2005/0135231 A1 6/2005 Bellovin
2005/0136832 A1 6/2005 Spreizer
2005/0157810 A1 7/2005 Raleigh et al.
2005/0159824 A1 7/2005 Childress
2005/0172016 A1 8/2005 Kossi et al.
2005/0174975 A1 8/2005 Mgrdechian et al.
2005/0195915 A1 9/2005 Raleigh et al.
2005/0195960 A1 9/2005 Shaffer et al.
2005/0225365 A1 10/2005 Wood
2005/0240427 A1 10/2005 Crichlow
2005/0251434 A1 11/2005 Ouimet
2005/0251771 A1 11/2005 Robles
2005/0254106 A9 11/2005 Silverbrook et al.

2005/0281270 A1 12/2005 Kossi et al.
2005/0289612 A1 12/2005 Morton et al.
2006/0033713 A1 2/2006 Pryor
2006/0039362 A1 2/2006 Yegoshin
2006/0039696 A1 2/2006 Saniee et al.
2006/0051022 A1 3/2006 Levner et al.
2006/0051090 A1 3/2006 Saniee et al.
2006/0062376 A1 3/2006 Pickford
2006/0067234 A1 3/2006 Bossi et al.
2006/0095877 A1 5/2006 Su et al.
2006/0136310 A1 6/2006 Gonen et al.
2006/0143587 A1 6/2006 Boutin et al.
2006/0153356 A1 7/2006 Sisselman et al.
2006/0158330 A1 7/2006 Gueziec
2006/0167784 A1 7/2006 Hoffberg
2006/0202953 A1 9/2006 Pryor et al.
2006/0206854 A1 9/2006 Barnes et al.
2006/0214000 A1 9/2006 Lapstun et al.
2006/0215825 A1 9/2006 Boutin et al.
2006/0229742 A1 10/2006 Boutin et al.
2006/0237546 A1 10/2006 Lapstun et al.
2006/0241990 A1 10/2006 Sun et al.
2006/0242017 A1 10/2006 Libes et al.
2006/0249577 A1 11/2006 Silverbrook et al.
2006/0262922 A1* 11/2006 Margulies G06Q 30/02
379/265.12

2006/0265234 A1 11/2006 Peterkofsky et al.
2006/0266828 A1 11/2006 Silverbrook et al.
2006/0293951 A1 12/2006 Patel et al.
2007/0005808 A1 1/2007 Day
2007/0013551 A1 1/2007 Gueziec
2007/0019754 A1 1/2007 Raleigh et al.
2007/0021998 A1 1/2007 Laithwaite et al.
2007/0025351 A1 2/2007 Cohen
2007/0033170 A1 2/2007 Sull et al.
2007/0033292 A1 2/2007 Sull et al.
2007/0033515 A1 2/2007 Sull et al.
2007/0033521 A1 2/2007 Sull et al.
2007/0033533 A1 2/2007 Sull
2007/0038362 A1 2/2007 Gueziec
2007/0038612 A1 2/2007 Sull et al.
2007/0044010 A1 2/2007 Sull et al.
2007/0064912 A1 3/2007 Kagan et al.
2007/0071222 A1 3/2007 Flockhart et al.
2007/0073486 A1 3/2007 Tillotson et al.
2007/0087756 A1 4/2007 Hoffberg
2007/0115800 A1 5/2007 Fonseka et al.
2007/0140374 A1 6/2007 Raleigh et al.
2007/0150387 A1 6/2007 Seubert et al.
2007/0150846 A1 6/2007 Furnish et al.
2007/0174180 A1 7/2007 Shin
2007/0196047 A9 8/2007 Levner et al.
2007/0204252 A1 8/2007 Furnish et al.
2007/0235532 A1 10/2007 Lapstun et al.
2007/0260723 A1 11/2007 Cohen et al.
2007/0264008 A1 11/2007 Zaacks et al.
2007/0272735 A1 11/2007 Silverbrook et al.
2007/0272748 A1 11/2007 Silverbrook et al.
2008/0040254 A1 2/2008 Waelbroeck et al.
2008/0043634 A1 2/2008 Wang et al.
2008/0065576 A1 3/2008 Friedlander et al.
2008/0071946 A1 3/2008 Lapstun et al.
2008/0077463 A1 3/2008 Friedlander et al.
2008/0093459 A1 4/2008 Lapstun et al.
2008/0109153 A1 5/2008 Gueziec
2008/0112053 A1 5/2008 Levner et al.
2008/0120129 A1 5/2008 Seubert et al.
2008/0122786 A1 5/2008 Pryor et al.
2008/0140597 A1 6/2008 Satir et al.
2008/0147655 A1 6/2008 Sinha et al.
2008/0148196 A1 6/2008 Su et al.
2008/0149710 A1 6/2008 Silverbrook et al.
2008/0172352 A1 7/2008 Friedlander et al.
2008/0177687 A1 7/2008 Friedlander et al.
2008/0177688 A1 7/2008 Friedlander et al.
2008/0189306 A1 8/2008 Hewett et al.
2008/0204429 A1 8/2008 Silverbrook et al.
2008/0205501 A1 8/2008 Cioffi et al.
2008/0216025 A1 9/2008 Furnish et al.

US 10,491,748 B1

Page 12

(56)

References Cited

U.S. PATENT DOCUMENTS

2008/0216028 A1	9/2008	Su et al.	2010/0192212 A1	7/2010	Raleigh
2008/0216038 A1	9/2008	Bose	2010/0201516 A1	8/2010	Gelvin et al.
2008/0216039 A1	9/2008	Furnish et al.	2010/0219244 A1	9/2010	Silverbrook et al.
2008/0216040 A1	9/2008	Furnish et al.	2010/0232445 A1	9/2010	Bellovin
2008/0219268 A1	9/2008	Dennison	2010/0235285 A1	9/2010	Hoffberg
2008/0251585 A1	10/2008	Silverbrook et al.	2010/0238521 A1	9/2010	Rusman et al.
2008/0262893 A1	10/2008	Hoffberg	2010/0268447 A1	10/2010	Griffiths
2008/0265026 A1	10/2008	Silverbrook et al.	2010/0281151 A1	11/2010	Ramankutty et al.
2008/0265027 A1	10/2008	Silverbrook et al.	2010/0284388 A1	11/2010	Fantini et al.
2008/0265028 A1	10/2008	Silverbrook et al.	2010/0291907 A1	11/2010	MacNaughtan et al.
2008/0270259 A1	10/2008	Silverbrook et al.	2010/0317420 A1	12/2010	Hoffberg
2008/0272193 A1	11/2008	Silverbrook et al.	2010/0332401 A1	12/2010	Prahlad et al.
2008/0315978 A1	12/2008	Knight et al.	2010/0332454 A1	12/2010	Prahlad et al.
2009/0010189 A1	1/2009	Nagra et al.	2010/0332456 A1	12/2010	Prahlad et al.
2009/0014526 A1	1/2009	Rusman et al.	2010/0332479 A1	12/2010	Prahlad et al.
2009/0031271 A1	1/2009	White et al.	2010/0332818 A1	12/2010	Prahlad et al.
2009/0032599 A1	2/2009	Rusman et al.	2010/0333116 A1	12/2010	Prahlad et al.
2009/0034972 A1	2/2009	Fiaschi et al.	2011/0004513 A1	1/2011	Hoffberg
2009/0083211 A1	3/2009	Sinha et al.	2011/0019771 A1	1/2011	Raleigh et al.
2009/0084850 A1	4/2009	Silverbrook et al.	2011/0022881 A1	1/2011	Nakata
2009/0084857 A1	4/2009	Silverbrook et al.	2011/0035491 A1	2/2011	Gelvin et al.
2009/0125448 A1	5/2009	Borkovec et al.	2011/0059798 A1	3/2011	Pryor
2009/0129771 A1	5/2009	Sanjee et al.	2011/0078640 A1	3/2011	Bruneel
2009/0145966 A1	6/2009	Silverbrook et al.	2011/0093492 A1	4/2011	Sull et al.
2009/0180736 A1	7/2009	Levner et al.	2011/0106617 A1	5/2011	Cooper et al.
2009/0216910 A1	8/2009	Duchesneau	2011/0132424 A1	6/2011	Rakib
2009/0231996 A1	9/2009	Lauther	2011/0143811 A1	6/2011	Rodriguez
2009/0234917 A1	9/2009	Despotovic et al.	2011/0169660 A1	7/2011	Gueziec
2009/0252134 A1	10/2009	Schlicht et al.	2011/0212717 A1	9/2011	Rhoads et al.
2009/0254874 A1	10/2009	Bose	2011/0228678 A1	9/2011	Ricciulli
2009/0261171 A1	10/2009	Lapstun et al.	2011/0261049 A1	10/2011	Cardno et al.
2009/0265206 A1	10/2009	Friedlander et al.	2011/0310996 A1	12/2011	Raleigh et al.
2009/0281864 A1	11/2009	Abercrombie et al.	2012/0033217 A1	2/2012	Levner et al.
2009/0299853 A1	12/2009	Jones et al.	2012/0039529 A1	2/2012	Rujan
2009/0306866 A1	12/2009	Malikopoulos	2012/0040755 A1	2/2012	Pryor
2009/0307641 A1	12/2009	Su et al.	2012/0088470 A1	4/2012	Raleigh
2009/0307644 A1	12/2009	Su et al.	2012/0089721 A1	4/2012	Day
2009/0309758 A1	12/2009	Gueziec	2012/0089845 A1	4/2012	Raleigh
2009/0314834 A1	12/2009	Lapstun et al.	2012/0101952 A1	4/2012	Raleigh et al.
2009/0316627 A1	12/2009	Fonseka et al.	2012/0106428 A1	5/2012	Schlicht et al.
2009/0322561 A1	12/2009	Morioka et al.	2012/0108163 A1	5/2012	Bai et al.
2009/0327148 A1	12/2009	Kamar et al.	2012/0123980 A1	5/2012	Bhandari et al.
2010/0014784 A1	1/2010	Silverbrook et al.	2012/0134291 A1	5/2012	Raleigh
2010/0042726 A1	2/2010	Luzon et al.	2012/0137336 A1	5/2012	Applegate et al.
2010/0046040 A1	2/2010	Rusman et al.	2012/0151422 A1	6/2012	White et al.
2010/0072275 A1	3/2010	Lapstun et al.	2012/0166371 A1	6/2012	Sweeney et al.
2010/0091906 A1	4/2010	Raleigh et al.	2012/0166372 A1	6/2012	Ilyas et al.
2010/0096450 A1	4/2010	Silverbrook et al.	2012/0166373 A1	6/2012	Sweeney et al.
2010/0140352 A1	6/2010	Silverbrook et al.	2012/0176900 A1	7/2012	Steer et al.
2010/0142421 A1	6/2010	Schlicht et al.	2012/0191332 A1	7/2012	Sawhill et al.
2010/0142445 A1	6/2010	Schlicht et al.	2012/0191333 A1	7/2012	Sawhill et al.
2010/0142446 A1	6/2010	Schlicht et al.	2012/0192249 A1	7/2012	Raleigh
2010/0142447 A1	6/2010	Schlicht et al.	2012/0195206 A1	8/2012	Raleigh
2010/0142448 A1	6/2010	Schlicht et al.	2012/0195222 A1	8/2012	Raleigh
2010/0148940 A1	6/2010	Gelvin et al.	2012/0195223 A1	8/2012	Raleigh
2010/0150120 A1	6/2010	Schlicht et al.	2012/0196565 A1	8/2012	Raleigh
2010/0165982 A1	7/2010	Yegoshin	2012/0197686 A1	8/2012	Abu El Ata
2010/0188975 A1	7/2010	Raleigh	2012/0197792 A1	8/2012	Raleigh
2010/0188990 A1	7/2010	Raleigh	2012/0201133 A1	8/2012	Raleigh
2010/0188991 A1	7/2010	Raleigh	2012/0203677 A1	8/2012	Raleigh
2010/0188992 A1	7/2010	Raleigh	2012/0208496 A1	8/2012	Raleigh
2010/0188993 A1	7/2010	Raleigh	2012/0209750 A1	8/2012	Raleigh
2010/0188994 A1	7/2010	Raleigh	2012/0210391 A1	8/2012	Raleigh
2010/0188995 A1	7/2010	Raleigh	2012/0214441 A1	8/2012	Raleigh
2010/0190470 A1	7/2010	Raleigh	2012/0232679 A1	9/2012	Abercrombie et al.
2010/0191575 A1	7/2010	Raleigh	2012/0238272 A1	9/2012	Hwang et al.
2010/0191576 A1	7/2010	Raleigh	2012/0242501 A1	9/2012	Tran et al.
2010/0191604 A1	7/2010	Raleigh	2012/0254333 A1	10/2012	Chandramouli et al.
2010/0191612 A1	7/2010	Raleigh	2012/0290202 A1	11/2012	Gueziec
2010/0191613 A1	7/2010	Raleigh	2012/0290204 A1	11/2012	Gueziec
2010/0191846 A1	7/2010	Raleigh	2012/0290464 A1	11/2012	Borkovec et al.
2010/0191847 A1	7/2010	Raleigh	2012/0294195 A1	11/2012	Raleigh
2010/0192120 A1	7/2010	Raleigh	2013/0003613 A1	1/2013	Raleigh
2010/0192170 A1	7/2010	Raleigh	2013/0005299 A1	1/2013	Raleigh
2010/0192207 A1	7/2010	Raleigh	2013/0005322 A1	1/2013	Raleigh
			2013/0006729 A1	1/2013	Raleigh
			2013/0006780 A1	1/2013	Raleigh
			2013/0024424 A1	1/2013	Prahlad et al.
			2013/0033385 A1	2/2013	Gueziec

US 10,491,748 B1

Page 13

(56)

References Cited

U.S. PATENT DOCUMENTS

2013/0040703	A1	2/2013	Raleigh	2014/0310243	A1	10/2014	McGee et al.
2013/0045710	A1	2/2013	Raleigh	2014/0317315	A1	10/2014	Duchesneau
2013/0046723	A1	2/2013	Sweeney et al.	2014/0320315	A1	10/2014	Gueziec
2013/0058431	A1	3/2013	Fonseka et al.	2014/0354350	A1	12/2014	Bowers et al.
2013/0060785	A1	3/2013	Sweeney et al.	2014/0359683	A1	12/2014	Applegate et al.
2013/0066823	A1	3/2013	Sweeney et al.	2014/0379588	A1	12/2014	Gates et al.
2013/0069780	A1	3/2013	Tran et al.	2015/0011194	A1	1/2015	Rodriguez
2013/0072149	A1	3/2013	Raleigh	2015/0012210	A1	1/2015	Griffiths
2013/0080307	A1	3/2013	Hoffberg	2015/0012495	A1	1/2015	Prahlad et al.
2013/0080607	A1	3/2013	Raleigh	2015/0039962	A1	2/2015	Fonseka et al.
2013/0083701	A1	4/2013	Tomic et al.	2015/0039964	A1	2/2015	Fonseka et al.
2013/0096998	A1	4/2013	Raleigh	2015/0039965	A1	2/2015	Fonseka et al.
2013/0097301	A1	4/2013	Day	2015/0046582	A1	2/2015	Gelvin et al.
2013/0125219	A1	5/2013	Raleigh	2015/0067618	A1	3/2015	Robles
2013/0132578	A1	5/2013	Raleigh	2015/0072641	A1	3/2015	Raleigh et al.
2013/0132854	A1	5/2013	Raleigh et al.	2015/0089399	A1	3/2015	Megill et al.
2013/0133028	A1	5/2013	Raleigh	2015/0105631	A1	4/2015	Tran et al.
2013/0135008	A1	5/2013	Zhang et al.	2015/0111591	A1	4/2015	Hoffberg
2013/0138428	A1	5/2013	Chandramouli et al.	2015/0120706	A1	4/2015	Hoffman et al.
2013/0169527	A1	7/2013	Pryor	2015/0120941	A1	4/2015	Ramankutty et al.
2013/0178718	A1	7/2013	Tran et al.	2015/0142807	A1	5/2015	Hofmann et al.
2013/0179034	A1	7/2013	Pryor	2015/0146592	A1	5/2015	Zendle
2013/0207817	A1	8/2013	Gueziec	2015/0149078	A1	5/2015	Profous et al.
2013/0208823	A1	8/2013	Raleigh et al.	2015/0154873	A1	6/2015	Sawhill et al.
2013/0215795	A1	8/2013	Raleigh	2015/0163694	A1	6/2015	Raleigh
2013/0227659	A1	8/2013	Raleigh	2015/0180509	A9	6/2015	Fonseka et al.
2013/0229951	A1	9/2013	Raleigh	2015/0195414	A1	7/2015	Raleigh
2013/0231084	A1	9/2013	Raleigh	2015/0195714	A1	7/2015	Raleigh
2013/0235766	A1	9/2013	Raleigh	2015/0200882	A1	7/2015	Raleigh
2013/0238572	A1	9/2013	Prahlad et al.	2015/0201331	A1	7/2015	Raleigh
2013/0239194	A1	9/2013	Raleigh	2015/0201333	A1	7/2015	Raleigh
2013/0249791	A1	9/2013	Pryor	2015/0215786	A1	7/2015	Raleigh
2013/0250768	A1	9/2013	Raleigh	2015/0224845	A1	8/2015	Anderson et al.
2013/0267318	A1	10/2013	Pryor et al.	2015/0254566	A1	9/2015	Chandramouli et al.
2013/0305322	A1	11/2013	Raleigh et al.	2015/0268055	A1	9/2015	Gueziec
2013/0306276	A1	11/2013	Duchesneau	2015/0268056	A1	9/2015	Gueziec
2013/0329526	A1	12/2013	Rakib	2015/0286915	A1	10/2015	Rujan
2013/0332983	A1	12/2013	Koorevaar et al.	2015/0295772	A1	10/2015	Bouda
2014/0022460	A1	1/2014	Li et al.	2015/0296279	A1	10/2015	Bouda
2014/0024340	A1	1/2014	Raleigh	2015/0304498	A1	10/2015	McCord et al.
2014/0039963	A1	2/2014	Augenstein et al.	2015/0304797	A1	10/2015	Rhoads et al.
2014/0040282	A1	2/2014	Mann et al.	2015/0325123	A1	11/2015	Gueziec
2014/0055284	A1	2/2014	Tran et al.	2015/0331972	A1	11/2015	McClure et al.
2014/0080428	A1	3/2014	Rhoads et al.	2015/0377632	A1	12/2015	Pfeifle
2014/0081793	A1	3/2014	Hoffberg	2015/0381649	A1	12/2015	Schultz et al.
2014/0088871	A1	3/2014	Gueziec	2016/0019795	A1	1/2016	Chircop et al.
2014/0091950	A1	4/2014	Gueziec	2016/0028610	A1	1/2016	Kohli
2014/0094159	A1	4/2014	Raleigh et al.	2016/0034305	A1	2/2016	Shear et al.
2014/0098671	A1	4/2014	Raleigh et al.	2016/0036500	A1	2/2016	Kohli
2014/0107923	A1	4/2014	Gueziec	2016/0037431	A1	2/2016	Kohli
2014/0113583	A1	4/2014	Raleigh	2016/0054137	A1	2/2016	Wheatman et al.
2014/0121476	A1	5/2014	Tran et al.	2016/0054735	A1	2/2016	Switkes et al.
2014/0129040	A1	5/2014	Emadi et al.	2016/0066788	A1	3/2016	Tran et al.
2014/0129779	A1	5/2014	Frachtenberg et al.	2016/0087846	A1	3/2016	Prasad et al.
2014/0136107	A1	5/2014	Pfeifle	2016/0112821	A1	4/2016	Raleigh
2014/0163850	A1	6/2014	Sawhill et al.	2016/0119001	A1	4/2016	Fonseka et al.
2014/0173078	A1	6/2014	McCord et al.	2016/0127977	A1	5/2016	Kohli
2014/0188378	A1	7/2014	Sawhill et al.	2016/0155073	A1	6/2016	Augenstein et al.
2014/0195406	A1	7/2014	Borkovec et al.	2016/0156587	A1	6/2016	Day
2014/0198687	A1	7/2014	Raleigh	2016/0171412	A1	6/2016	McHugh et al.
2014/0211786	A1	7/2014	Yegoshin	2016/0224951	A1	8/2016	Hoffberg
2014/0235230	A1	8/2014	Raleigh	2016/0226563	A1	8/2016	Kohli
2014/0241314	A1	8/2014	Raleigh et al.	2016/0226569	A1	8/2016	Kohli
2014/0248852	A1	9/2014	Raleigh et al.	2016/0231047	A1	8/2016	Kendall et al.
2014/0258557	A1	9/2014	Day	2016/0236790	A1	8/2016	Knapp et al.
2014/0265808	A1	9/2014	Kendall et al.	2016/0239851	A1	8/2016	Tanner, Jr. et al.
2014/0277599	A1	9/2014	Pande et al.	2016/0248631	A1	8/2016	Duchesneau
2014/0277872	A1	9/2014	MacNeille et al.	2016/0255199	A1	9/2016	McCord et al.
2014/0278089	A1	9/2014	Gusikhin et al.	2016/0266939	A1	9/2016	Shear et al.
2014/0278091	A1	9/2014	Horvitz et al.	2016/0302047	A1	10/2016	Gueziec
2014/0280952	A1	9/2014	Shear et al.	2016/0321529	A1	11/2016	Rujan
2014/0282586	A1	9/2014	Shear et al.	2016/0323279	A1	11/2016	Raleigh
2014/0286156	A1	9/2014	Kohli	2016/0330567	A1	11/2016	Raleigh
2014/0286251	A1	9/2014	Kohli	2016/0335893	A1	11/2016	Gueziec
2014/0288995	A1	9/2014	Huff et al.	2016/0359665	A1	12/2016	Raleigh
				2016/0373588	A1	12/2016	Raleigh et al.
				2016/0379168	A1	12/2016	Foerster et al.
				2017/0004250	A1	1/2017	Robles
				2017/0006135	A1	1/2017	Siebel et al.

US 10,491,748 B1

(56)

References Cited

U.S. PATENT DOCUMENTS

2017/0015312 A1 1/2017 Latotzki
2017/0031613 A1 2/2017 Lee et al.
2017/0031784 A1 2/2017 Lee et al.
2017/0039218 A1 2/2017 Prahlad et al.
2017/0055132 A9 2/2017 Gueziec
2017/0060102 A1 3/2017 Sargolzaei et al.
2017/0078922 A1 3/2017 Raleigh et al.
2017/0089635 A9 3/2017 Kendall et al.
2017/0109841 A1 4/2017 Sadikovic
2017/0111223 A1 4/2017 Matni et al.
2017/0116566 A1 4/2017 Walton
2017/0132853 A1 5/2017 Matos et al.
2017/0156119 A1 6/2017 Neves et al.
2017/0171580 A1 6/2017 Hirsch et al.
2017/0171834 A1 6/2017 Neves et al.
2017/0182859 A1 6/2017 Anderson et al.
2017/0201850 A1 7/2017 Raleigh et al.
2017/0206512 A1 7/2017 Hoffberg
2017/0206529 A1 7/2017 Raleigh
2017/0215028 A1 7/2017 Rhoads et al.
2017/0215073 A1 7/2017 Raleigh
2017/0223516 A1 8/2017 Raleigh
2017/0236407 A1 8/2017 Rhoads et al.
2017/0270709 A1 9/2017 Tran et al.
2017/0272349 A1 9/2017 Hopkins et al.
2017/0279843 A1 9/2017 Schultz et al.
2017/0279971 A1 9/2017 Raleigh et al.
2017/0287212 A1 10/2017 Tran et al.
2017/0289323 A1 10/2017 Gelvin et al.
2017/0308097 A1 10/2017 Switkes et al.
2017/0309092 A1 10/2017 Rosenbaum

2017/0314944 A1 11/2017 Konig et al.
2017/0314945 A1 11/2017 Konig et al.
2017/0322578 A1 11/2017 Baone et al.
2017/0332240 A1 11/2017 Raleigh
2017/0337711 A1 11/2017 Ratner et al.
2017/0347026 A1 11/2017 Hannuksela
2017/0352202 A1 12/2017 Matos et al.
2017/0374013 A1 12/2017 Day
2018/0011180 A1 1/2018 Warnick et al.
2018/0011766 A1 1/2018 Lee et al.
2018/0027473 A1 1/2018 Kalogridis et al.
2018/0035391 A1 2/2018 Neves et al.
2018/0040250 A1 2/2018 Sawhill et al.
2018/0049043 A1 2/2018 Hoffberg
2018/0064402 A1 3/2018 Leydon
2018/0068358 A1 3/2018 Hoffberg
2018/0069786 A1 3/2018 Lokman et al.
2018/0101802 A1 4/2018 Fox et al.
2018/0134106 A9 5/2018 Anderson et al.
2018/0134400 A1 5/2018 Knapp et al.
2018/0141363 A1 5/2018 Pandey
2018/0145725 A1 5/2018 Pandey
2018/0150777 A1 5/2018 Han et al.
2018/0167309 A1 6/2018 Teboulle et al.
2018/0189990 A1 7/2018 Cardno et al.
2018/0191867 A1 7/2018 Siebel et al.
2018/0231487 A1 8/2018 Miled et al.
2018/0233028 A1 8/2018 Rhoads et al.
2018/0246766 A1 8/2018 Holmberg et al.
2018/0247191 A1 8/2018 Katz et al.
2018/0253906 A1 9/2018 Tran et al.
2018/0260512 A1 9/2018 Robles
2018/0260892 A1 9/2018 Mueller et al.
2018/0261020 A1 9/2018 Petousis et al.

* cited by examiner

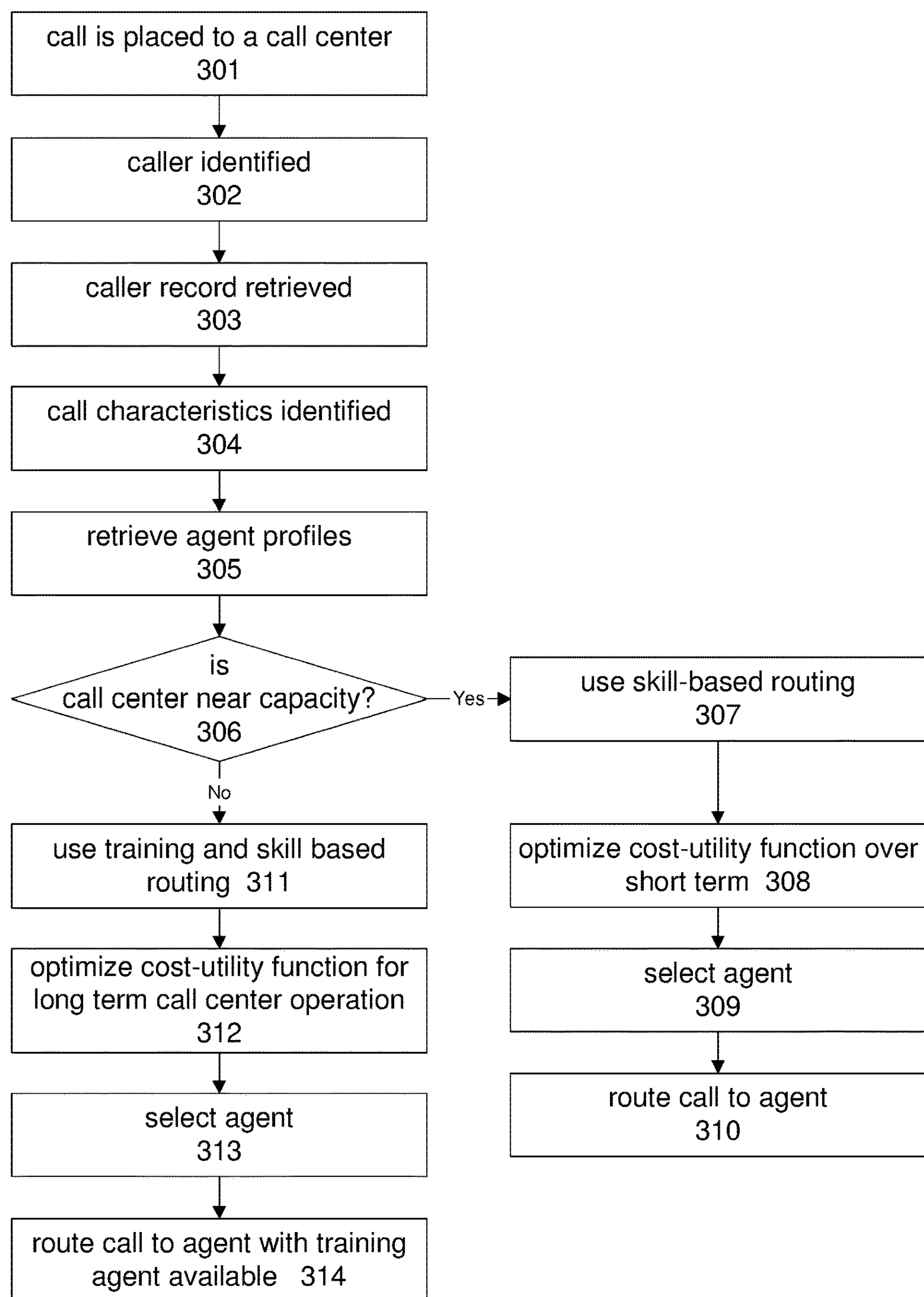


Fig. 1

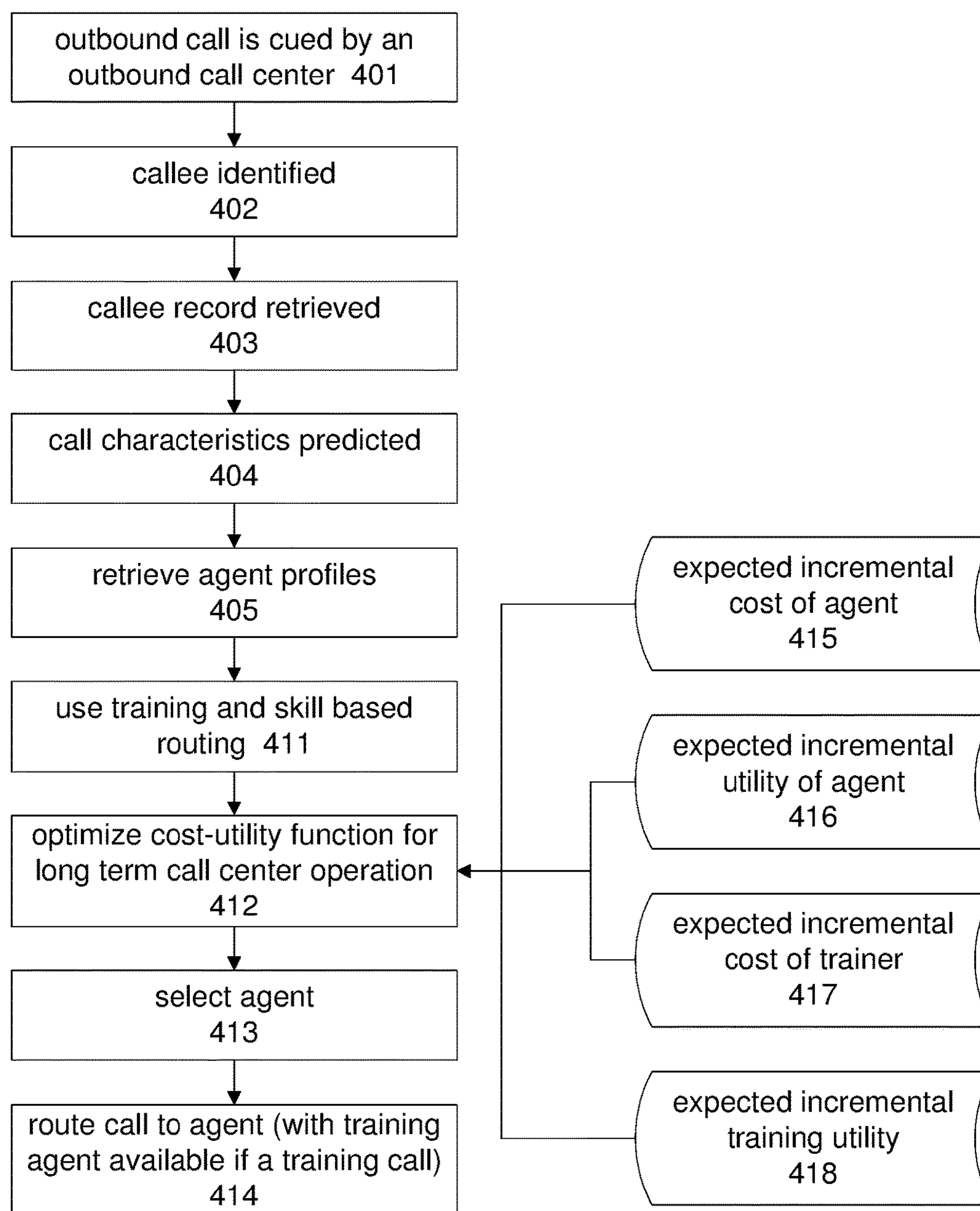


Fig. 2

Rule vector			Agent	Agent	Agent	Agent	Agent
			1	2	3	4	5
20%		Skill 1	20	5	3	5	4
5%		Skill 2	3	3	3	3	3
10%		Skill 3	10	6	9	10	10
15%		Skill 4	43	50	33	46	25
3%		Skill 5	7	2	9	2	8
7%		Skill 6	5	8	5	8	9
20%		Skill 7	2	3	4	2	2
8%		Skill 8	64	80	29	45	77
5%		Skill 9	4	5	4	1	2
7%		Skill 10	9	3	8	3	6
100%		Score	18.51	17.33	11.1	13.93	13.65

Fig. 3

Rule Vector		Agent	Agent	Agent	Agent	Agent
		1	2	3	4	5
	Ac1	0.4	0.55	0.45	0.7	0.6
	Ac2	6	3	6.8	2	5.5
20%	Skill 1	20	5	3	5	4
5%	Skill 2	3	3	3	3	3
10%	Skill 3	10	6	9	10	10
15%	Skill 4	43	50	33	46	25
3%	Skill 5	7	2	9	2	8
7%	Skill 6	5	8	5	8	9
20%	Skill 7	2	3	4	2	2
8%	Skill 8	64	80	29	45	77
5%	Skill 9	4	5	4	1	2
7%	Skill 10	9	3	8	3	6
100%	Prelim Score	18.51	17.33	11.1	13.93	13.65
	Final Score	13.40	12.53	11.80	11.75	13.69

Fig. 4

Rule Vector					Agent	Agent	Agent	Agent	Agent
	Min Skill	Max Skill	Exclude Agent		1	2	3	4	5
			Ac1		0.4	0.55	0.45	0.7	0.6
			Ac2		6	3	6.8	2	5.5
20%	0%	25%		Skill 1	20	5	3	5	4
5%				Skill 2	3	3	3	3	3
10%				Skill 3	10	6	9	10	10
15%	40%	100%	3, 5	Skill 4	43	50	33	46	25
3%				Skill 5	7	2	9	2	8
7%				Skill 6	5	8	5	8	9
20%				Skill 7	2	3	4	2	2
8%	30%	75%	2, 3, 5	Skill 8	64	80	29	45	77
5%				Skill 9	4	5	4	1	2
7%				Skill 10	9	3	8	3	6
			2, 3, 5 excluded						
			1, 4 available						
100%				Prelim Score	18.51	17.33	11.1	13.93	13.65
				Final Score	13.40	12.53	11.80	11.75	13.69

Fig. 5

SKILL	Rule Vector 1	Rule Vector 2	Rule Vector 3	Rule Vector 4	Rule Vector 5		Agent 1	Agent 2	Agent 3	Agent 4	Agent 5
							1	2	3	4	5
1	20%	25%	17%	20%	14%		20	5	3	5	4
2	5%	10%	5%	5%	3%		3	3	3	3	3
3	10%	15%	20%	10%	8%		10	6	9	10	10
4	15%	10%	5%	5%	5%		43	50	33	46	25
5	3%	0%	5%	8%	1%		7	2	9	2	8
6	7%	10%	13%	10%	7%		5	8	5	8	9
7	20%	10%	5%	10%	20%		2	3	4	2	2
8	8%	4%	8%	4%	8%		64	80	29	45	77
9	5%	8%	13%	18%	23%		4	5	4	1	2
10	7%	8%	9%	10%	11%		9	3	8	3	6
	100%	100%	100%	100%	100%	Rule 1	18.51	17.33	11.1	13.93	13.65
						Rule 2	15.4	12.39	8.72	10.77	10.12
						Rule 3	15.25	13.31	8.97	10.54	12.71
						Rule 4	12.74	9.91	7.6	7.89	8.98
						Rule 5	13.69	12.83	8.24	9.03	11.09

Fig. 6

Combinatorial analysis of agents vs. callers

58.85	59.52	58.77	59.58	60.68	58.79	58.04	58.85	60.28	57.72	58.12	58.93	60.42	57.86	59.01	60.15	59.26	56.7	59.96	58.18
57.88	58.55	58.88	60.66	59.71	57.82	58.15	59.93	59.31	56.75	55.41	57.19	60.53	57.97	56.3	57.33	60.34	57.78	57.25	55.36
60.13	61.28	59.25	60.06	61.96	61.33	59.3	60.11	62.04	60.26	58.9	59.71	60.9	59.12	59.79	60.93	59.74	57.96	58.63	58.96
60.24	49.54	56.54	58.32	62.07	58.99	56.96	58.74	59.33	57.92	56.56	58.34	58.19	56.78	57.45	58.48	58	56.59	57.26	56.51
58.66	59.81	60.14	62.42	60.49	59.86	60.19	62.47	60.57	58.79	57.45	59.73	61.79	60.01	58.34	58.59	62.1	60.32	58.65	56.62
59.74	58.07	57.32	59.6	61.57	58.49	57.74	60.02	58.83	57.42	57.82	60.1	58.97	57.56	58.71	58.96	59.28	57.87	59.02	56.99

Fig. 7

	Rule Vector 1	Rule Vector 2	Rule Vector 3	Rule Vector 4	Rule Vector 5		Agent	Agent	Agent	Agent	Agent	Agent
SKILL												
Caller time factor	3	3.5	2.75	4	10		1	2	3	4	5	
						Agent Cost	0.59	0.68	1	0.86	0.79	
						Agent time factor	1.3	1.3	1	1.1	1.2	
1	20%	25%	17%	20%	14%		20	5	3	5	4	
2	5%	10%	5%	5%	3%		3	3	3	3	3	
3	10%	15%	20%	10%	8%		10	6	9	10	10	
4	15%	10%	5%	5%	5%		43	50	33	46	25	
5	3%	0%	5%	8%	1%		7	2	9	2	8	
6	7%	10%	13%	10%	7%		5	8	5	8	9	
7	20%	10%	5%	10%	20%		2	3	4	2	2	
8	8%	4%	8%	4%	8%		64	80	29	45	77	
9	5%	8%	13%	18%	23%		4	5	4	1	2	
10	7%	8%	9%	10%	11%		9	3	8	3	6	
	100%	100%	100%	100%	100%	Rule 1	72.189	58.80069	19.647	31.71861	36.855	
						Rule 2	70.07	49.045815	18.0068	28.610505	31.878	
						Rule 3	54.51875	41.3974275	14.553825	21.999615	31.45725	
						Rule 4	66.248	44.83284	17.936	23.95404	32.328	
						Rule 5	177.97	145.1073	48.616	68.5377	99.81	

Fig. 8

Combinatorial Analysis

259.5527	255.3573	256.8383	289.6307	267.1886	254.8785	256.3595	289.1519	255.0903	246.9756	247.4191	280.2116	264.8651	256.7504	255.7129	291.0701	309.1051	300.9904	367.4349	302.5176
236.6543	232.4589	235.0236	290.7144	244.2902	231.9801	234.5448	290.2356	232.1919	224.0773	219.4143	275.1051	243.0504	234.9358	277.7081	284.8799	310.1888	302.0741	339.4301	296.3275
260.9804	259.9429	259.9962	292.7886	268.6163	260.932	260.9853	293.7777	259.6759	253.0292	248.887	281.6795	268.023	261.3763	257.1808	292.538	312.263	305.6163	301.4208	303.9855
239.1658	163.4004	231.9914	287.6822	246.8016	234.7961	234.8494	290.5402	231.6711	226.8933	222.7511	278.4419	240.0182	235.2403	231.0449	288.2167	307.1566	302.3787	298.1833	299.6643
224.1784	223.1409	225.7056	295.3001	231.8143	224.13	226.6947	296.2892	222.8739	216.2272	211.5642	281.1587	233.7324	227.0857	219.858	289.5057	314.7744	308.1277	300.9300	9533
225.2621	218.0345	219.5155	289.1099	232.898	220.8925	222.3735	291.9679	217.7675	212.9896	213.4331	283.0276	227.5423	222.7644	221.7269	291.3746	308.5843	303.8064	302.7689	302.8222

Fig. 9

US 10,491,748 B1

1

**INTELLIGENT COMMUNICATION
ROUTING SYSTEM AND METHOD**

RELATED APPLICATIONS

The present application is a Continuation of U.S. patent application Ser. No. 14/968,114, filed Dec. 14, 2015, now U.S. Pat. No. 9,807,239, issued Oct. 31, 2017, which is a Continuation of U.S. patent application Ser. No. 13,661,293, filed Oct. 26, 2012, now U.S. Pat. No. 9,215,322, issued Dec. 15, 2015, which is a Continuation of U.S. patent application Ser. No. 11/695,691, filed Apr. 3, 2007, now U.S. Pat. No. 8,300,798, issued Oct. 30, 2012, which is a non-provisional of U.S. Provisional Patent Application 60/744,190, filed Apr. 3, 2006, the entirety of which are expressly incorporated herein by reference.

FIELD OF THE INVENTION

The present invention relates generally to computer integrated telecommunications systems and more particularly to a system and method employing an intelligent switching architecture.

BACKGROUND ART

The description of the invention herein is intended to provide information for one skilled in the art to understand and practice the full scope of the invention, but is not intended to be limiting as to the scope of available knowledge, nor admit that any particular reference, nor the combinations and analysis of this information as presented herein, is itself a part of the prior art. It is, in fact, a part of the present invention to aggregate the below cited information as a part of the disclosure, without limiting the scope thereof. All of the below-identified references are therefore expressly incorporated herein by reference, as if the entirety thereof was recited completely herein. It is particularly noted that the present invention is not limited by a narrow or precise discussion herein, nor is it intended that any disclaimer, limitation, or mandatory language as applied to any embodiment or embodiments be considered to limit the scope of the invention as a whole. The scope of the invention is therefore to be construed as the entire literal scope of the claims, as well as any equivalents thereof as provided by law. It is also understood that the title, abstract, field of the invention, and dependent claims are not intended to, and do not, limit the scope of the independent claims.

Real-time communications are typically handled by dedicated systems which assure that the management and control operations are handled in a manner to keep up with the communications process, and to avoid imposing inordinate delays. In order to provide cost-effective performance, complex processes incidental to the management or control of the communication are typically externalized. Thus, the communications process is generally unburdened from tasks requiring a high degree of intelligence, for example the evaluation of complex algorithms and real time optimizations. One possible exception is least cost routing (LCR), which seeks to employ a communications channel which is anticipated to have a lowest cost per unit. In fact, LCR schemes, when implemented in conjunction with a communications switch, either employ simple predetermined rules, or externalize the analysis.

Modern computer telephone integrated systems typically employ a general purpose computer with dedicated voice-communication hardware peripherals, for example boards

2

made by Dialogic, Inc. (Intel Corp.). The voice communication peripherals execute the low level processing and switching of the voice channels, under control from the general purpose processor. Therefore, the voice-information is generally not communicated on the computer bus. This architecture typically allows the computing platform to run a modern, non-deterministic operating system, such as Windows 2000, without impairing the real-time performance of the system as a whole, since the communications control functions are not as time critical as the voice processing functions. However, as is well known, non-deterministic operating systems, such as Windows 2000, are subject to significant latencies, especially when multiple tasks are executing, and when contention exists between resources, especially hard disk access and virtual memory. Therefore, in order to assure that system operation is unimpeded by inconsistent demands on the platform, typically the host computer system for the telephony peripherals is 'dedicated', and attempts are made to eliminate extraneous software tasks. On the other hand, externalizing essential functions imposes potential latencies due to communications and external processing.

The Call Center

A 'call center' is an organization of people, telecommunications equipment and management software, with a mission of efficiently handling electronic customer contact. A typical call center must balance competing goals. Customers should experience high quality and consistent service as measured, for example, by how long the customer's call must wait in queue before being answered and receiving satisfactory service. At the same time, this service should be provided to make efficient use of call center resources.

Strategies for Call Center Management

'Workforce management' systems provide important tools for meeting the goals of the call center. These systems generate forecasts of call volumes and call handling times based on historical data, to predict how much staff will be needed at different times of the day and week. The systems then create schedules that match the staffing to anticipated needs. Typically, an Automatic Call Distribution (ACD) function is provided in conjunction with a computerized Private Branch Exchange (PBX). This ACD function enables a group of agents, termed ACD agents, to handle a high volume of inbound calls and simultaneously allows a queued caller to listen to recordings when waiting for an available ACD agent. The ACD function typically informs inbound callers of their status while they wait and the ACD function routes callers to an appropriate ACD agent on a first-come-first-served basis. Today, all full-featured PBXs provide the ACD function and there are even vendors who provide switches specifically designed to support the ACD function. The ACD function has been expanded to provide statistical reporting tools, in addition to the call queuing and call routing functions mentioned above, which statistical reporting tools are used to manage the call center. For example, ACD historical reports enable a manager to identify times: (a) when inbound callers abandon calls after long waits in a queue because, for example, the call center is staffed by too few ACD agents and (b) when many ACD agents are idle. In addition, ACD forecasting reports, based on the historical reports, allow the manager to determine appropriate staffing levels for specific weeks and months in the future.

Queue Management

ACD systems experience high traffic periods and low traffic periods. Consequently, ACD systems must be capable of automating two major decisions. The first major decision

US 10,491,748 B1

3

may be referred to as the ‘agent selection decision,’ i.e., when more than one agent is available to handle the next transaction, which agent should be chosen? The second major decision may be referred to as the ‘transaction selection decision,’ i.e., when more than one transaction is waiting for the next available agent and an agent becomes available, which transaction should the agent handle? One approach to the agent selection decision is to set up a sequencing scheme, so that the switch of the ACD system follows the same sequence of agents until the first available agent in the sequence is found. The concern with this approach is that it creates ‘hot seats,’ i.e. an inequitable distribution of inbound calls to ACD agents who are high in the sequence. Most current ACD systems solve the agent selection decision by using a longest-idle-eligible-agent approach to provide a more equitable distribution of transactions.

There are also different approaches to the transaction selection decision in which there are more available transactions than there are ACD agents. One approach is to create one or more first-in, first-out (FIFO) queues. Under this approach, each transaction may be marked with a priority level by the switch of the ACD system. When an agent becomes available, the transaction with the highest priority is routed to the agent. If several calls of equal priority are waiting in a queue, the call which has been waiting the longest is routed to the available agent. If the call center conducts outbound transactions, each transaction is similarly submitted to a FIFO queue with a priority designation, with the switch routing transactions from the queue to the agents.

Queue/Team Management

Calls that arrive at a call center generally are classified into ‘call types’ based on the dialed number and possibly other information such as calling number or caller responses to prompts from the network. The call center is typically served by an automatic call distributor (ACD), which identifies the call type of each incoming call and either delivers or queues it. Each call type may have a separate first-in-first-out queue in the ACD. In most existing call centers, the agents answering calls are organized into one or more ‘teams,’ with each team having primary responsibility of the calls in one or more queues. This paradigm is sometimes referred to as ‘queue/team.’ In the queue/team model, scheduling for each team can be done independently. Suppose, for example, that the call center handles calls for sales, service, and billing, and that each of these call types is served by a separate team. The schedule for sales agents will depend on the forecast for sales call volume and on various constraints and preferences applicable to the agents being scheduled, but this schedule is not affected by the call volume forecast for service or billing. Further, within the sales team, agents are typically considered interchangeable from a call handling viewpoint. Thus, within a team, schedule start times, break times and the like, may be traded freely among agents in the team to satisfy agent preferences without affecting scheduled call coverage. See, U.S. Pat. No. 5,325,292, expressly incorporated herein by reference. In a queue/team environment, when a new call arrived, the ACD determines the call type and places it in the queue, if all agents are busy, or allocates this call to the team member who had been available the longest.

Skill-Based Routing

Skill-based routing of agents is a well known principle, in which the agent with the best match of skills to the problem presented is selected for handling the matter. Typically, these matters involve handling of telephone calls in a call center, and the technology may be applied to both inbound and

4

outbound calling, or a combination of each. The skill-based routing algorithms may also be used to anticipate call center needs, and therefore be used to optimally schedule agents for greatest efficiency, lowest cost, or other optimized variable.

In the case of multi-skill criteria, the optimality of selection may be based on a global minimization of the cost function or the like.

The longest-idle-agent approach and the FIFO approach function well in applications having little variation in the types of transactions being handled by the ACD agents. If all agents can handle any transaction, these approaches provide a sufficiently high level of transactional throughput, i.e., the number of transactions handled by the call center in a particular time interval. However, in many call center environments, the agents are not equally adept at performing all types of transactions. For example, some transactions of a particular call center may require knowledge of a language other than the native language of the country in which the call center is located. As another example, some transactions may require the expertise of ‘specialists’ having training in the specific field to which the transaction relates, since training all agents to be knowledgeable in all areas would be cost-prohibitive. For ACD applications in which agents are not equally adept at performing all transactions, there are a number of problems which at least potentially reduce transactional throughput of the call center. Three such problems may be referred to as the ‘under-skilled agent’ problem, the ‘over-skilled agent’ problem, and the ‘static grouping’ problem.

The under-skilled agent problem reduces transactional throughput when the switch routes transactions to ACD agents who do not have sufficient skills to handle the transactions. For example, a call may be routed to an English-only speaking person, even though the caller only speaks Spanish. In another example, the transaction may relate to product support of a particular item for which the agent is not trained. When this occurs, the agent will typically apologize to the customer and transfer the call to another agent who is capable of helping the customer. Consequently, neither the agent’s nor the customer’s time is efficiently utilized.

Inefficient utilization is also a concern related to the over-skilled agent problem. A call center may have fixed groupings of agents, with each group having highly trained individuals and less-experienced individuals. Call-management may also designate certain agents as ‘specialists,’ since it would be cost prohibitive to train all agents to be experts in all transactions. Ideally, the highly skilled agents handle only those transactions that require a greater-than-average skill level. However, if a significant time passes without transactions that require highly skilled agents, the agents may be assigned to calls for which they are over-qualified. This places the system in a position in which there is no qualified agent for an incoming call requiring a particular expertise because the agents having the expertise are handling calls that do not require such expertise. Again, the transactional throughput of the call center is reduced.

Current ACD systems allow agents to be grouped according to training. For example, a product support call center may be divided into four fixed, i.e., ‘static,’ groups, with each group being trained in a different category of products sold by the company. There are a number of potentially negative effects of static grouping. Firstly, the call center management must devise some configuration of agents into groups. This may be a costly process requiring extensive analysis and data entry. Secondly, the configuration that is devised is not likely to be optimal in all situations. The pace

US 10,491,748 B1

5

and mix of transactions will change during a typical day. At different times, the adverse effects of the under-skilled agent problem and the adverse effects of the over-skilled agent problem will vary with respect to the transactional throughput of the call center. Thirdly, when a new product is released, the devised configuration likely will be less valuable. In response to changes in the size, pace and mix of the transaction load over the course of time, call management must monitor and adjust the performance of the current grouping configuration on an ongoing basis. When trends are detected, the grouping configuration should be changed. This requires the time and attention of call center managers and supervisors. Again, the transactional throughput is reduced.

It is thus known in the prior art to provide ACD systems that depart from the queue/team model described above. Calls are still categorized into call types. In place of queues for the call types, however, queues associated with 'skills' are provided. The ACD's call distribution logic for the call type determines which queue or queues a call will occupy at various times before it is answered. Agents are not organized into teams with exclusive responsibility for specific queues. Instead, each agent has one or more identified 'skills' corresponding to the skills-based queues. Thus, both a given call and a given agent may be connected to multiple queues at the same time. Agent skills designations may be further qualified, for example, as 'primary' or 'secondary' skills, or with some other designation of skill priority or degree of skill attainment. The ACD call distribution logic may take the skill priority levels into account in its call distribution logic.

In a skills-based routing environment, the 'matching' of calls to agents by the ACD becomes more sophisticated and thus complicated. Agents who have more than one skill no longer 'belong' to a well-defined team that handles a restricted set of calls. Instead, the skills definitions form 'implicit' teams that overlap in complex ways. If, for example, a call center has 10 skills defined, then agents could in principle have any of 1024 possible combinations (2^{10}) of those skills. Each skill combination could be eligible to handle a different subset of the incoming calls, and the eligible subset might vary with time of day, number of calls in queue, or other factors used by the ACD in its call routing decisions. Today, call center managers want to connect a caller to an ACD agent having exactly the right skills to serve the caller. However, 'skills based' ACD agent groups are often small and, as a result, whenever an inbound call arrives, all such 'skills based' ACD agents may be busy. In such instances, the ACD function can take call back instructions from the caller and the ACD function can manage the call back functions, for example, by assigning such calls, in accordance with the caller instructions, to a 'skills based' ACD agent whenever one becomes available.

Scheduling of agents in a skills-based environment is thus a much more difficult problem than it is in a queue/team environment. In a skills-based environment, call types cannot be considered in isolation. Thus, for example, a heavy volume of Service calls might place higher demands on multi-skilled agents, causing an unforeseen shortage of coverage for Billing calls. Further, agents with different skills cannot be considered interchangeable for call handling. Thus, trading lunch times between a Sales-only agent and a multi-skill agent might lead to over-staffing Sales at noon while under-staffing Service at 1:00 p.m. This would lead to undesirable results. Moreover, with respect to the needs of a particular call type, a multi-skilled agent might provide no help over a given span of time, might be 100%

6

available for calls of that type, or might be available part of the time and handling other call types for another part of time.

All agents having a particular combination of skills may be deemed a 'skill group.' A central problem of skills-based scheduling is then finding a way to predict what fraction of scheduled agents from each skill group will be available to each call type during each time interval being scheduled. If these fractions are known, then the effect of different agent schedules can be generated. Unfortunately, it is difficult or impossible to calculate the skill group availability fractions directly. These functions depend on the relative and absolute call volumes in each call type, on the particulars of the skills-based call distribution algorithms in the ACD, and on the skills profiles of the total scheduled agent population. Particularly as ACD skills-based routing algorithms themselves evolve and become more sophisticated, the factors affecting skill group availability become too complex for direct analysis. One proposed solution provides a feedback mechanism involving call handling simulation and incremental scheduling, to schedule agents in a skills-based routing environment. See, U.S. Pat. No. 6,044,355, expressly incorporated herein in its entirety.

In accordance with this 'skills-based scheduling' method, a computer implemented tool is used to determine an optimum schedule for a plurality of scheduled agents in a telephone call center, each of the plurality of scheduled agents having a combination of defined skills. The plurality of scheduled agents are organized into 'skill groups' with each group including all scheduled agents having a particular combination of skills. The method begins by generating a plurality of net staffing arrays, each net staff array associated with a given call type and defining, for each time interval to be scheduled, an estimate of a difference between a given staffing level and a staffing level needed to meet a current call handling requirement. In addition to the net staffing arrays, the method uses a plurality of skills group availability arrays, each skills group availability array associated with the given call type and defining, for each combination of skill group and time interval to be scheduled, an estimate of a percentage of scheduled agents from each skill group that are available to handle a call. According to the method, the plurality of arrays are used to generate a proposed schedule for each of the plurality of scheduled agents. Thereafter, a call handling simulation is then run against the proposed schedule using a plurality of ACD call distribution algorithms (one for each call type being scheduled). Based on the results of the call handling simulation, the net staffing arrays and the skills availability arrays are refined to more accurately define the net staffing and skills usage requirements. The process of generating a schedule and then testing that schedule through the simulator is then repeated until a given event occurs. The given event may be a determination that the schedule meets some given acceptance criteria, a passage of a predetermined period of time, a predetermined number of iterations of the process, or some combination thereof. A proposed schedule is 'optimized' when it provides an acceptable call handling performance level and an acceptable staffing level in the simulation. Once the proposed schedule is 'optimized,' it may be further adjusted (within a particular skill group) to accommodate agent preferences.

U.S. Pat. No. 5,206,903 to Kohler et al. describes ACD equipment which uses static grouping. Each static group of agents is referred to as a 'split,' and each split is associated with a different queue. The agents are assigned to splits according to skills. Within a single split, the agents may be

US 10,491,748 B1

7

limited to knowledge of different subtypes of transactions. Preferably, there is at least one agent in each split who is trained to handle calls of any of the subtypes within the particular split. This 'expert' may also be trained to efficiently handle calls of other types, i.e., other splits. Each agent possesses up to four skill numbers that represent various abilities of the agent with respect to handling transactions related to subtypes and types of transactions. The ACD equipment assigns each incoming call three prioritized skill numbers that estimate skill requirements of the incoming call. The skill numbers of the incoming call are considered 'prioritized,' since they are viewed sequentially in searching for a match of the call with an agent, so that the second skill number of the call is unnecessary if a match is found using the first prioritized skill number. The incoming call is assigned the one, two or three prioritized skill numbers and is placed in the appropriate queue of the appropriate static group of agents. A search is made among the available agents for an agent-skill number that matches the first skill number of the call. If no match is found after a predetermined time delay, the second prioritized skill number of the call is used to find a match. If no match is found after a second predetermined time delay, the third prioritized skill number is considered. Then, if no match is still found, the ACD equipment of Kohler et al. expands the search of available agents to other groups of agents.

While the Kohler et al. patent does not directly address the problems associated with static groups, it does consider the skills of the individual agents. The prioritized skill numbers assigned to the incoming calls are logically ordered. The patent refers to the first skill number of a call as the primary call-skill indicator. This primary indicator is used to define the minimal skill level that is required for an agent to competently handle the call. Consequently, if a match is made with the primary indicator, the ACD agent may not be over-skilled or under-skilled. However, if the search is unsuccessful, the secondary call-skill indicator is utilized. The search for a match to the secondary indicator may cause the call to be routed to an agent having more than the minimal required skill. The third prioritized skill number that is assigned to the incoming call is referred to as the 'tertiary' call-skill indicator. The tertiary indicator is yet another skill level beyond what is minimally required to competently handle a call. Since the tertiary indicator is utilized only if a match is not found for either of the primary or secondary indicators, an overly skilled agent of the appropriate group will handle the call only if that agent is the only available capable agent. Thus, more highly skilled agents are assigned only when their skills are required, or no lesser-skilled agent is available to handle the call.

See, U.S. Pat. Nos. 6,529,870; 6,522,726; 6,519,459; 6,519,259; 6,510,221; 6,496,568; 6,493,696; 6,493,432; 6,487,533; 6,477,494; 6,477,245; 6,470,077; 6,466,909; 6,466,654; 6,463,299; 6,459,784; 6,453,038; and U.S. Published Patent Application No. 2003/0002646.

Group Routing

Various types of conventional automatic distributors (ACDs) are available to distribute incoming calls to a group. Reservation and information services may be provided by large companies, such as major airlines, and may consist of geographically separated groups of agents that answer incoming calls distributed to the agents by separate ACDs. Agent communication terminals (ACTs) which are connected to an ACD are utilized by the agents to process incoming calls routed to a particular ACT by the ACD.

A public branch exchange (PBX) type ACD such as a Definity® ACD available from AT&T functions as a con-

8

ventional PBX and further functions as an ACD to distribute incoming calls to local agents connected to the PBX. Another type of ACD consists of the utilization of an electronic telecommunication switch such as a 5ESS® switch available from AT&T which is capable of providing ACD service when supposed by ACTs coupled to the switch. Both types of ACD typically function as independent systems which handle incoming calls and make internal decisions concerning which agent will receive a given call. Both types of ACD systems are capable of generating statistical reports which can be monitored by a workstation coupled to the ACD system to allow a supervisor to monitor call handling statistics. Such data typically represents an average of statistics for a given system.

Telephone call centers that handle calls to toll-free '800' numbers are well-known in the art. Typically, a company may have many call centers, all answering calls made to the same set of 800 numbers. Each of the company's call centers usually has an automatic call distributor (ACD) or similar equipment capable of queuing calls. ACD management information systems keep statistics on agent and call status, and can report these statistics on frequent intervals. Such capabilities are in use today for centralized reporting and display of multi-location call center status. In such systems, the company will want to distribute the calls to its call centers in a way that will optimally meet its business goals. Those goals might include low cost of call handling, answering most calls within a given amount of time, providing customized handling for certain calls, and many others. It is also known in the prior art that certain call routing criteria and techniques support a broad range of business goals. These include 'load balancing,' 'caller segmentation' and 'geographic routing.' Load balancing refers to distribution of calls so that the expected answer delay for new calls is similar across all the call centers. If other considerations do not dictate otherwise, load balancing is desirable because it provides optimum efficiency in the use of agents and facilities, and it provides the most consistent grade of service to callers. In special situations it might be desirable to unbalance the load in a particular way, but control over the distribution of call load is still desired.

If the caller's identity can be inferred from the calling number, caller-entered digits, or other information, that identity may influence the choice of destination for the call. Call routing based on such information is referred to as caller segmentation. Also, it has been found desirable for particular call centers to handle calls from particular geographic areas. The motivation may be to minimize call transport costs, to support pre-defined call center 'territories', or to take advantage of agents specifically trained to handle calls from given locations. Such techniques are known as geographic routing.

The interexchange carriers who provide 800 service today generally support some form of 'routing plan' to help achieve load balancing, caller segmentation and geographic routing. Typically these routing plans allow 800 call routing based on time of day, day of week, the caller's area code, caller-entered digits, and fixed percentage allocations. Predominately, however, the routing plans supported by the carriers are static in the sense that they do not automatically react to unexpected variations in incoming call volume or distribution, nor to actual call delays being experienced at each destination. Reaction to changing conditions is done via manual modification of the plan, on a time scale of minutes or hours. Recent service offerings from some interexchange carriers offer some degree of automatic reaction to changing conditions. One such offering, called 'alternate

US 10,491,748 B1

9

termination sequence' or 'ATS' (from AT&T), allows customers to establish maximum numbers of calls to be queued for each destination, with a pre-defined alternative when a primary destination is overloaded. Another offering, referred to as 'intelligent routing control' or 'IRC' (from MCI), allows an ACD to refuse a call from the network, again resulting in pre-defined alternative call handling. A third kind of service, AT&T's Intelligent Call Processing, lets the interexchange network pass call-by-call data to a computer.

In a conventional ACD, phone calls are processed on a first-in, first-out basis: the longest call waiting is answered by the next available agent. Answering calls across multiple automated call distributors (ACD) is typically done on a first-in, first-out basis dependent upon time of receipt of the call by each ACD, whether the call is directly connected or forwarded. Another call distribution scheme is provided in Gechter et al., U.S. Pat. No. 5,036,535. This patent discloses a system for automatically distributing telephone calls placed over a network to one of a plurality of agent stations connected to the network via service interfaces, and providing status messages to the network. Gechter et al.'s disclosed system includes means for receiving the agent status messages and call arrival messages from the network, which means are connected via a network service interface to the network. Routing means responsive to the receiving means is provided for generating a routing signal provided to the network to connect the incoming call to an agent station through the network. In the system disclosed in Gechter et al, when an incoming call is made to the call router, it decides which agent station should receive the call, establishes a call with that agent station, and then transfers the original call onto the second call to connect the incoming caller directly to the agent station and then drops out of the connection. U.S. Pat. No. 5,193,110 issued to Jones et al discloses an integrated services platform for a telephone communications system which platform includes a plurality of application processing ports for providing different types of information services to callers. In Jones et al's disclosed system, a master control unit and a high speed digital switch are used to control processing of incoming phone calls by recognizing the type of service requested by the caller and then routing the call to the appropriate processing port. The Jones et al system is disclosed as an adjunct to current switching technology in public and private networks.

Intelligent Call Management

Call centers are also used to make outbound calls, for example for telemarketing. Agents making outbound calls, referred to as outbound agents, are typically separate from ACD agents handling inbound calls and call center software separately manages outbound call lists for outbound agents to ensure that each outbound agent wastes little time in dialing or in performing overhead operations. A call center typically has multiple agents for answering incoming calls and placing outgoing calls. A call center may also have agents participating in outgoing call campaigns, typically in conjunction with an outbound call management system. Each agent may be assigned to a particular group, such as an inbound group or an outbound group. Agents can also be assigned to a supervisor team, which represents multiple agents that report to the same supervisor.

In certain situations, it is necessary to restrict an agent's activity to answering calls or handling a particular type of call (e.g., answering only incoming calls). For example, during an outbound campaign, the system placing the outbound calls and controlling the rate at which the calls are placed, e.g., a so-called predictive dialer, relies on the availability of the agent to handle an answered call. If the

10

system places outbound calls expecting the agent to be available, but the agent instead places their own call to another agent or a supervisor, or has an incoming call connected to them, the outbound system may not have an agent available to handle an answered outbound call. Additionally, if an agent is assigned to handle incoming calls, but instead places a call to another agent or listens to voice mail messages, the number of queued incoming calls may increase, thereby increasing the waiting time experienced by the callers. 'ITU-T Recommendation Q.1219, Intelligent Network User's Guide for Capability Set 1', dated April, 1994, expressly incorporated herein by reference, provides considerable information on intelligent networks. One known system proposes a call-management method and system for distributing calls to a plurality of individuals, such as automatic call distribution (ACD) agents, which routes calls to the individuals based upon a correlation of attributes of the individuals with calls that are tagged with identification of abilities that are advantageous to efficiently processing the calls. That is, for each call that is to be distributed, one or more skills that are relevant to efficient handling of the call are determined and then used to route the call to an appropriate individual. In addition, call management preferences may also be accommodated.

Personalization and Collaborative Filtering

Known systems allow personalization or prediction of user type, preferences or desires based on historical data or limited information available. These known systems have been applied to a number of different domains. In a non-collaborative personalization system, the available information about a person is analyzed, and based on this information, conclusions are drawn. In a collaborative system, the available information is used to associate the person with a group of other users having common attributes. By grouping users, the data sets are more dense, permitting more detailed inferences to be drawn. The groups are defined by mapping user attributes in a multidimensional space, and then defining clusters of users having correlated traits. Further, the use of data relating to past transactions of other users allows prediction of outcomes and sequences of actions, without having a true past example of the activity from that particular user.

The following references are expressly incorporated herein by reference: U.S. Pat. Nos. 6,418,424; 6,400,996; 6,081,750; 5,920,477; 5,903,454; 5,901,246; 5,875,108; 5,867,386; 5,774,357; 6,529,891; 6,466,970; 6,449,367; 6,446,035; 6,430,558; 6,412,012; 6,389,372; 6,356,899; 6,334,131; 6,334,127; 6,327,590; 6,321,221; 6,321,179; 6,317,722; 6,317,718; 6,266,649; 6,256,648; 6,253,193; 6,236,980; 6,236,978; 6,185,683; 6,177,932; 6,170,742; 6,146,026; 6,138,119; 6,112,186; 6,112,181; 6,078,928; 6,016,475; 5,999,908; 5,560,011; 6,484,123; 6,480,844; 6,477,246; 6,421,709; 6,405,922; 6,353,813; 6,345,264; 6,314,420; 6,308,175; 6,144,964; 6,029,161; 6,018,738; 6,016,475; 6,006,218; 5,983,214; 5,867,799; and 5,790,935. See also references cited in U.S. patent application Ser. No. 10/385,389. See, U.S. Pat. Nos. 4,048,452; 4,737,983; 4,757,529; 4,893,301; 4,953,204; 5,073,890; 5,278,898; 5,309,513; 5,369,695; 5,506,898; 5,511,117; 5,519,773; 5,524,147; 5,590,188; 5,633,922; 5,633,924; 5,715,307; 5,740,240; 5,768,360; 5,825,869; 5,848,143; 5,870,464; 5,878,130; 5,901,214; 5,905,792; 5,907,608; 5,910,982; 5,915,011; 5,917,903; 5,923,745; 5,926,539; 5,933,492; 5,940,496; 5,940,947; 5,946,387; 5,953,332; 5,953,405; 5,956,397; 5,960,073; 5,963,632; 5,970,134; 5,978,465; 5,982,868; 5,987,116; 5,987,118; 5,991,391; 5,991,392; 5,991,395; 5,995,614; 5,995,615; 5,999,965; 6,002,760;

US 10,491,748 B1

11

6,005,931; 6,044,146; 6,058,435; 6,061,347; 6,064,667;
6,072,864; 6,104,801; 6,115,462; 6,118,865; 6,122,358;
6,122,360; 6,122,364; 6,128,380; 6,134,530; 6,147,975;
6,157,655; 6,175,563; 6,175,564; 6,185,292; 6,223,165;
6,226,289; 6,229,888; 6,230,197; 6,233,332; 6,333,979;
6,333,980; 6,347,139; and U.S. Pat. App. Nos. 010000458
A1; 0010024497 A1; 0020006191 A1; 0020009190 A1;
0020019846 A1; and 0020021693 A1, each of which is
expressly incorporated herein by reference.

Internet Auctions

On-line electronic auction systems which allow efficient
sales of products and services are well known, for example,
EBAY.COM, ONSALE.COM, UBID.COM, and the like. Inverse
auctions that allow efficient purchases of product are
also known, establishing a market price by competition
between sellers. The Internet holds the promise of further
improving efficiency of auctions by reducing transaction
costs and freeing the 'same time-same place' limitations of
traditional auctions. This is especially appropriate where the
goods may be adequately described by text or images, and
thus a physical examination of the goods is not required
prior to bidding.

In existing Internet systems, the technological focus has
been in providing an auction system that, over the course of
hours to days, allow a large number of simultaneous auc-
tions, between a large number of bidders to occur. These
systems must be scalable and have high transaction through-
put, while assuring database consistency and overall system
reliability. Even so, certain users may selectively exploit
known technological limitations and artifacts of the auction
system, including non-real time updating of bidding infor-
mation, especially in the final stages of an auction. Because
of existing bandwidth and technological hurdles, Internet
auctions are quite different from live auctions with respect
to psychological factors. Live auctions are often monitored
closely by bidders, who strategically make bids, based not
only on the 'value' of the goods, but also on an assessment
of the competition, timing, psychology, and progress of the
auction. It is for this reason that so-called proxy bidding,
wherein the bidder creates a preprogrammed 'strategy',
usually limited to a maximum price, are disfavored. A
maximum price proxy bidding system is somewhat ineffi-
cient, in that other bidders may test the proxy, seeking to
increase the bid price, without actually intending to pur-
chase, or contrarily, after testing the proxy, a bidder might
give up, even below a price he might have been willing to
pay. Thus, the proxy imposes inefficiency in the system that
effectively increases the transaction cost. In order to address
a flurry of activity that often occurs at the end of an auction,
an auction may be held open until no further bids are cleared
for a period of time, even if advertised to end at a certain
time. This is common to both live and automated auctions.
However, this lack of determinism may upset coordinated
schedules, thus impairing efficient business use of the auc-
tion system.

In order to facilitate management of bids and bidding,
some of the Internet auction sites have provided non-
Hypertext Markup Language (HTML) browser based soft-
ware 'applet' to track auctions. For example, ONSALE-
.COM has made available a Marimba Castanet® applet
called Bidwatch to track auction progress for particular
items or classes of items, and to facilitate bidding thereon.
This system, however, lacks real-time performance under
many circumstances, having a stated refresh period of 10
seconds, with a long latency for confirmation of a bid, due
to constraints on software execution, quality of service in
communications streams, and bid confirmation dialogue.

12

Thus, it is possible to lose a bid even if an attempt was made
prior to another bidder. The need to quickly enter the bid, at
risk of being too late, makes the process potentially error
prone. Proxy bidding, as discussed above, is a known
technique for overcoming the constraints of Internet com-
munications and client processing limitations, since it
bypasses the client and telecommunications links and may
execute solely on the host system or local thereto. However,
proxy bidding undermines some of the efficiencies gained by
a live market.

A known computer site for auctioning a product on-line
comprises at least one web server computer designed for
serving a host of computer browsers and providing the
browsers with the capability to participate in various auc-
tions, where each auction is of a single product, at a specified
time, with a specified number of the product available for
sale. The web server cooperates with a separate database
computer, separated from the web server computer by a
firewall. The database computer is accessible to the web
computer server computer to allow selective retrieval of
product information, which includes a product description,
the quantity of the product to be auctioned, a start price of
the product, and an image of the product. The web server
computer displays, updated during an auction, the current
price of the product, the quantity of the product remaining
available for purchase and the measure of the time remain-
ing in the auction. The current price is decreased in a
predetermined manner during the auction. Each user is
provided with an input instructing the system to purchase the
product at a displayed current price, transmitting an identi-
fication and required financial authorization for the purchase
of the product, which must be confirmed within a predeter-
mined time. In the known system, a certain fall-out rate in
the actual purchase confirmation may be assumed, and
therefore some overselling allowed. Further, after a purchase
is indicated, the user's screen is not updated, obscuring the
ultimate lowest selling price from the user. However, if the
user maintains a second browser, he can continue to monitor
the auction to determine whether the product could have
been purchased at a lower price, and if so, fail to confirm the
committed purchase and purchase the same goods at a lower
price while reserving the goods to avoid risk of loss. Thus,
the system is flawed, and may fail to produce an efficient
transaction or optimal price. An Internet declining price
auction system may provide the ability to track the price
demand curve, providing valuable marketing information.
For example, in trying to determine the response at different
prices, companies normally have to conduct market surveys.
In contrast, with a declining price auction, substantial infor-
mation regarding price and demand is immediately known.
The relationship between participating bidders and average
purchasers can then be applied to provide a conventional
price demand curve for the particular product.

U.S. Pat. No. 5,890,138 to Godin, et al. (Mar. 30, 1999),
expressly incorporated herein by reference in its entirety,
relates to an Internet auction system. The system implements
a declining price auction process, removing a user from the
auction process once an indication to purchase has been
received. See, Rockoff, T. E., Groves, M.; 'Design of an
Internet-based System for Remote Dutch Auctions', Internet
Research, v 5, n 4, pp. 10-16, MCB University Press, Jan. 1,
1995. U.S. Pat. No. 5,835,896, Fisher, et al., issued Nov. 10,
1998, expressly incorporated herein by reference in its
entirety, provides method and system for processing and
transmitting electronic auction information over the Internet,
between a central transaction server system and remote
bidder terminals. Those bids are recorded by the system and

US 10,491,748 B1

13

the bidders are updated with the current auction status information. When appropriate, the system closes the auction from further bidding and notifies the winning bidders and losers as to the auction outcome. The transaction server posts information from a database describing a lot available for purchase, receives a plurality of bids, stored in a bid database, in response to the information, and automatically categorizes the bids as successful or unsuccessful. Each bid is validated, and an electronic mail message is sent informing the bidder of the bid status. This system employs HTTP, and thus does not automatically update remote terminal screens, requiring the e-mail notification feature.

The auction rules may be flexible, for example including Dutch-type auctions, for example by implementing a price markdown feature with scheduled price adjustments, and English-type (progressive) auctions, with price increases corresponding to successively higher bids. In the Dutch type auction, the price markdown feature may be responsive to bidding activity over time, amount of bids received, and number of items bid for. Likewise, in the progressive auction, the award price may be dependent on the quantity desired, and typically implements a lowest successful bid price rule. Bids that are below a preset maximum posted selling price are maintained in reserve by the system. If a certain sales volume is not achieved in a specified period of time, the price is reduced to liquidate demand above the price point, with the new price becoming the posted price. On the other hand, if a certain sales volume is exceeded in a specified period of time, the system may automatically increase the price. These automatic price changes allow the seller to respond quickly to market conditions while keeping the price of the merchandise as high as possible, to the seller's benefit. A 'Proxy Bidding' feature allows a bidder to place a bid for the maximum amount they are willing to pay, keeping this value a secret, displaying only the amount necessary to win the item up to the amount of the currently high bids or proxy bids of other bidders. This feature allows bidders to participate in the electronic auction without revealing to the other bidders the extent to which they are willing to increase their bids, while maintaining control of their maximum bid without closely monitoring the bidding. The feature assures proxy bidders the lowest possible price up to a specified maximum without requiring frequent inquiries as to the state of the bidding. A 'Floating Closing Time' feature may also be implemented whereby the auction for a particular item is automatically closed if no new bids are received within a predetermined time interval, assuming an increasing price auction. Bidders thus have an incentive to place bids expeditiously, rather than waiting until near the anticipated close of the auction.

U.S. Pat. No. 5,905,975, Ausubel, issued May 18, 1999, expressly incorporated herein by reference in its entirety, relates to computer implemented methods and apparatus for auctions. The proposed system provides intelligent systems for the auctioneer and for the user. The auctioneer's system contains information from a user system based on bid information entered by the user. With this information, the auctioneer's system determines whether the auction can be concluded or not and appropriate messages are transmitted. At any point in the auction, bidders are provided the opportunity to submit not only their current bids, but also to enter future bids, or bidding rules which may have the opportunity to become relevant at future times or prices, into the auction system's database. Participants may revise their executory bids, by entering updated bids. Thus, at one extreme, a bidder who wishes to economize on his time may choose to enter his entire set of bidding rules into the

14

computerized system at the start of the auction, effectively treating this as a sealed-bid auction. At the opposite extreme, a bidder who wishes to closely participate in the auction may choose to constantly monitor the auction's progress and to submit all of his bids in real time. See also, U.S. patent application Ser. No. 08/582,901 filed Jan. 4, 1996, which provides a method for auctioning multiple, identical objects and close substitutes.

E-Commerce Systems

U.S. Pat. No. 5,946,669 (Polk, Aug. 31, 1999), expressly incorporated herein by reference, relates to a method and apparatus for payment processing using debit-based electronic funds transfer and disbursement processing using addendum-based electronic data interchange. This disclosure describes a payment and disbursement system, wherein an initiator authorizes a payment and disbursement to a collector and the collector processes the payment and disbursement through an accumulator agency. The accumulator agency processes the payment as a debit-based transaction and processes the disbursement as an addendum-based transaction. The processing of a debit-based transaction generally occurs by electronic funds transfer (EFT) or by financial electronic data interchange (FEDI). The processing of an addendum-based transaction generally occurs by electronic data interchange (EDI).

U.S. Pat. No. 6,005,939 (Fortenberry, et al., Dec. 21, 1999), expressly incorporated herein by reference, relates to a method and apparatus for storing an Internet user's identity and access rights to World Wide Web resources. A method and apparatus for obtaining user information to conduct secure transactions on the Internet without having to re-enter the information multiple times is described. The method and apparatus can also provide a technique by which secured access to the data can be achieved over the Internet. A passport containing user-defined information at various security levels is stored in a secure server apparatus, or passport agent, connected to computer network. A user process instructs the passport agent to release all or portions of the passport to a recipient node and forwards a key to the recipient node to unlock the passport information.

U.S. Pat. No. 6,016,484 (Williams, et al., Jan. 18, 2000), expressly incorporated herein by reference, relates to a system, method and apparatus for network electronic payment instrument and certification of payment and credit collection utilizing a payment. An electronic monetary system provides for transactions utilizing an electronic-monetary system that emulates a wallet or a purse that is customarily used for keeping money, credit cards and other forms of payment organized. Access to the instruments in the wallet or purse is restricted by a password to avoid unauthorized payments. A certificate form must be completed in order to obtain an instrument. The certificate form obtains the information necessary for creating a certificate granting authority to utilize an instrument, a payment holder and a complete electronic wallet. Electronic approval results in the generation of an electronic transaction to complete the order. If a user selects a particular certificate, a particular payment instrument holder will be generated based on the selected certificate. In addition, the issuing agent for the certificate defines a default bitmap for the instrument associated with a particular certificate, and the default bitmap will be displayed when the certificate definition is completed. Finally, the number associated with a particular certificate will be utilized to determine if a particular party can issue a certificate.

U.S. Pat. No. 6,029,150 (Kravitz, Feb. 22, 2000), expressly incorporated herein by reference, relates to a

US 10,491,748 B1

15

system and method of payment in an electronic payment system wherein a plurality of customers have accounts with an agent. A customer obtains an authenticated quote from a specific merchant, the quote including a specification of goods and a payment amount for those goods. The customer sends to the agent a single communication including a request for payment of the payment amount to the specific merchant and a unique identification of the customer. The agent issues to the customer an authenticated payment advice based only on the single communication and secret shared between the customer and the agent and status information, which the agent knows about the merchant, and/or the customer. The customer forwards a portion of the payment advice to the specific merchant. The specific merchant provides the goods to the customer in response to receiving the portion of the payment advice.

U.S. Pat. No. 6,047,269 (Biffar, Apr. 4, 2000), expressly incorporated herein by reference, relates to a self-contained payment system with creating and facilitating transfer of circulating digital vouchers representing value. A digital voucher has an identifying element and a dynamic log. The identifying element includes information such as the transferable value, a serial number and a digital signature. The dynamic log records the movement of the voucher through the system and accordingly grows over time. This allows the system operator to not only reconcile the vouchers before redeeming them, but also to recreate the history of movement of a voucher should an irregularity like a duplicate voucher be detected. These vouchers are used within a self-contained system including a large number of remote devices that are linked to a central system. The central system can be linked to an external system. The external system, as well as the remote devices, is connected to the central system by any one or a combination of networks. The networks must be able to transport digital information, for example the Internet, cellular networks, telecommunication networks, cable networks or proprietary networks. Vouchers can also be transferred from one remote device to another remote device. These remote devices can communicate through a number of methods with each other. For example, for a non-face-to-face transaction the Internet is a choice, for a face-to-face or close proximity transactions tone signals or light signals are likely methods. In addition, at the time of a transaction a digital receipt can be created which will facilitate a fast replacement of vouchers stored in a lost remote device.

Micropayments

U.S. Pat. No. 5,999,919 (Jarecki, et al., Dec. 7, 1999), expressly incorporated herein by reference, relates to an efficient micropayment system. Existing software proposals for electronic payments can be divided into 'on-line' schemes which require participation of a trusted party (the bank) in every transaction and are secure against overspending, and 'off-line' schemes which do not require a third party and guarantee only that overspending is detected when vendors submit their transaction records to the bank (usually at the end of the day). A new 'hybrid' scheme is proposed which combines the advantages of both 'on-line' and 'off-line' electronic payment schemes. It allows for control of overspending at a cost of only a modest increase in communication compared to the off-line schemes. The protocol is based on probabilistic polling. During each transaction, with some small probability, the vendor forwards information about this transaction to the bank. This enables the bank to maintain an accurate approximation of a customer's spending. The frequency of polling messages is related to the monetary value of transactions and the amount of

16

overspending the bank is willing to risk. For transactions of high monetary value, the cost of polling approaches that of the on-line schemes, but for micropayments, the cost of polling is a small increase over the traffic incurred by the off-line schemes.

Micropayments are often preferred where the amount of the transaction does not justify the costs of complete financial security. In the micropayment scheme, typically a direct communication between creditor and debtor is not required; rather, the transaction produces a result which eventually results in an economic transfer, but which may remain outstanding subsequent to transfer of the underlying goods or services. The theory underlying this micropayment scheme is that the monetary units are small enough such that risks of failure in transaction closure is relatively insignificant for both parties, but that a user gets few chances to default before credit is withdrawn. On the other hand, the transaction costs of a non-real time transactions of small monetary units are substantially less than those of secure, unlimited or potentially high value, real time verified transactions, allowing and facilitating such types of commerce. Thus, the rights management system may employ applets local to the client system, which communicate with other applets and/or the server and/or a vendor/rights-holder to validate a transaction, at low transactional costs.

The following U.S. Patents, expressly incorporated herein by reference, define aspects of micropayment, digital certificate, and on-line payment systems: U.S. Pat. Nos. 5,930,777; 5,857,023; 5,815,657; 5,793,868; 5,717,757; 5,666,416; 5,677,955; 5,839,119; 5,915,093; 5,937,394; 5,933,498; 5,903,880; 5,903,651; 5,884,277; 5,960,083; 5,963,924; 5,996,076; 6,016,484; 6,018,724; 6,021,202; 6,035,402; 6,049,786; 6,049,787; 6,058,381; 6,061,448; 5,987,132; 6,057,872; and 6,061,665. See also, Rivest and Shamir, 'TayWord and MicroMint: Two Simple Micropayment Schemes' (May 7, 1996); Micro PAYMENT transfer Protocol (MPTP) Version 0.1 (22 Nov. 1995) et seq., <http://www.w3.org/pub/WWW/TR/WD-mptp>; Common Markup for web Micropayment Systems, <http://www.w3.org/TR/WD-Micropayment-Markup> (9 Jun. 1999); 'Distributing Intellectual Property: a Model of Microtransaction Based Upon Metadata and Digital Signatures', Olivia, Maurizio, <http://olivia.modlang.denison.edu/~olivia/RFC/09/>, all of which are expressly incorporated herein by reference.

See, Game Theory references cited in U.S. patent application Ser. No. 10/385,389. See, also: U.S. Pat. Nos. 4,977,595; 5,237,159; 5,392,353; 5,511,121; 5,621,201; 5,623,547; 5,679,940; 5,696,908; 5,754,939; 5,768,385; 5,799,087; 5,812,668; 5,828,840; 5,832,089; 5,850,446; 5,889,862; 5,889,863; 5,898,154; 5,901,229; 5,920,629; 5,926,548; 5,943,424; 5,949,045; 5,952,638; 5,963,648; 5,978,840; 5,983,208; 5,987,140; 6,002,767; 6,003,765; 6,021,399; 6,026,379; 6,029,150; 6,029,151; 6,047,067; 6,047,887; 6,055,508; 6,065,675; and 6,072,870, each of which is expressly incorporated herein by reference. See also, U.S. Pat. Nos. 6,243,684; 6,230,197; 6,229,888; 6,226,360; 6,226,287; 6,212,178; 6,208,970; 6,205,207; 6,201,950; 6,192,413; 6,192,121; 6,185,283; 6,178,240; 6,173,052; 6,170,011; RE37,001; 6,157,711; 6,154,535; 6,154,528; 6,151,387; 6,148,065; 6,144,737; 6,137,870; 6,137,862; 6,134,530; 6,130,937; 6,128,376; 6,125,178; 6,122,484; 6,122,364; 6,122,358; 6,115,693; 6,102,970; 6,098,069; 6,097,806; 6,084,943; 6,070,142; 6,067,348; 6,064,973; 6,064,731; 6,064,730; 6,058,435; 6,055,307; 6,052,453; 6,049,599; 6,044,368; 6,044,149; 6,044,135; 6,041,118; 6,041,116; 6,035,021; 6,031,899; 6,026,156; 6,026,149; 6,021,428; 6,021,190; 6,021,114; 6,018,579; 6,016,344;

US 10,491,748 B1

17

6,014,439; 6,011,845; 6,009,149; 6,005,928; 6,005,534;
 6,002,760; 5,995,948; RE36,416; 5,991,761; 5,991,604;
 5,991,393; 5,987,116; 5,987,115; 5,982,857; 5,978,471;
 5,978,467; 5,978,465; 5,974,135; 5,974,120; 5,970,132;
 5,966,429; 5,963,635; 5,956,392; 5,949,863; 5,949,854;
 5,949,852; 5,946,394; 5,946,388; 5,943,403; 5,940,813;
 5,940,497; 5,940,493; 5,937,390; 5,937,055; 5,933,480;
 5,930,339; 5,926,528; 5,924,016; 5,923,746; 5,918,213;
 5,917,893; 5,914,951; 5,913,195; 5,912,947; 5,907,601;
 5,905,979; 5,903,641; 5,901,209; 5,898,762; 5,898,759;
 5,896,446; 5,894,505; 5,893,902; 5,878,126; 5,872,833;
 5,867,572; 5,867,564; 5,867,559; 5,857,013; 5,854,832;
 5,850,428; 5,848,143; 5,841,852; 5,838,779; 5,838,772;
 5,835,572; 5,828,734; 5,828,731; 5,825,869; 5,822,410;
 5,822,401; 5,822,400; 5,815,566; 5,815,554; 5,815,551;
 5,812,642; 5,806,071; 5,799,077; 5,796,816; 5,796,791;
 5,793,846; 5,787,159; 5,787,156; 5,774,537; 5,768,355;
 5,761,285; 5,748,711; 5,742,675; 5,740,233; RE35,758;
 5,729,600; 5,727,154; 5,724,418; 5,717,741; 5,703,935;
 5,701,295; 5,699,418; 5,696,818; 5,696,809; 5,692,034;
 5,692,033; 5,687,225; 5,684,863; 5,675,637; 5,661,283;
 5,657,074; 5,655,014; 5,655,013; 5,652,788; 5,646,988;
 5,646,986; 5,638,436; 5,636,268; 5,636,267; 5,633,917;
 5,625,682; 5,625,676; 5,619,557; 5,610,978; 5,610,774;
 5,600,710; 5,594,791; 5,594,790; 5,592,543; 5,590,171;
 5,588,049; 5,586,179; 5,581,607; 5,581,604; 5,581,602;
 5,579,383; 5,579,377; 5,577,112; 5,574,784; 5,572,586;
 5,572,576; 5,570,419; 5,568,540; 5,561,711; 5,559,878;
 5,559,867; 5,557,668; 5,555,295; 5,555,290; 5,546,456;
 5,546,452; 5,544,232; 5,544,220; 5,537,470; 5,535,257;
 5,533,109; 5,533,107; 5,533,103; 5,530,931; 5,528,666;
 5,526,417; 5,524,140; 5,519,773; 5,517,566; 5,515,421;
 5,511,112; 5,506,898; 5,502,762; 5,495,528; 5,495,523;
 5,493,690; 5,485,506; 5,481,596; 5,479,501; 5,479,487;
 5,467,391; 5,465,286; 5,459,781; 5,448,631; 5,448,624;
 5,442,693; 5,436,967; 5,434,906; 5,432,835; 5,430,792;
 5,425,093; 5,420,919; 5,420,852; 5,402,474; 5,400,393;
 5,390,236; 5,381,470; 5,365,575; 5,359,645; 5,351,285;
 5,341,414; 5,341,412; 5,333,190; 5,329,579; 5,327,490;
 5,321,745; 5,319,703; 5,313,516; 5,311,577; 5,311,574;
 5,309,505; 5,309,504; 5,297,195; 5,297,146; 5,289,530;
 5,283,818; 5,276,732; 5,253,289; 5,251,252; 5,239,574;
 5,224,153; 5,218,635; 5,214,688; 5,185,786; 5,168,517;
 5,166,974; 5,164,981; 5,163,087; 5,163,083; 5,161,181;
 5,128,984; 5,121,422; 5,103,449; 5,097,528; 5,081,711;
 5,077,789; 5,073,929; 5,070,526; 5,070,525; 5,063,522;
 5,048,075; 5,040,208; 5,020,097; 5,020,095; 5,016,270;
 5,014,298; 5,007,078; 5,007,000; 4,998,272; 4,987,587;
 4,979,171; 4,975,841; 4,958,371; 4,941,168; 4,935,956;
 4,933,964; 4,930,150; 4,924,501; 4,894,857; 4,878,243;
 4,866,754; 4,852,149; 4,807,279; 4,797,911; 4,768,221;
 4,677,663; and 4,286,118, each of which is expressly incor-
 porated herein by reference.

SUMMARY AND OBJECTS OF THE INVENTION

The present invention provides a method and apparatus for optimizing the targeting of a communication with a destination, based on characteristics of the source or communication, characteristics of the destination, and the costs and benefits involved for each, especially where a plurality of sources are seeking to contact a plurality of destinations, e.g., simultaneously or otherwise inconsistently.

The disclosure describes a number of embodiments of the invention. Language describing one embodiment or set of

18

embodiments is not intended to, and does not, limit or constrain the scope of other embodiments of the invention.

The present invention provides, according to one embodiment, a system and method for intelligent communication routing within a low-level communication server system. Therefore, it allows replacement or supplementation of telephone numbers, IP addresses, e-mail addresses and the like, to identify targets accessible by the system with high-level definitions, which are contextually interpreted at the time of communications routing, to appropriately direct the communication. Therefore, the target of a communication is defined by an algorithm, rather than a predetermined address or simple rule, and the algorithm evaluated in real time for resolution of the target, to deliver the communication or establish a real or virtual channel.

According to another embodiment, the optimization and control is performed through a distributed architecture, and may be implemented at a high level.

Alternately, the intelligence of the server may be used to implement telephony or computer-telephony integration features, other than destination or target.

Therefore, according to the present invention, communications are, or may be, routed or other telecommunications features implemented, inferentially or intelligently, by a processor within the communications management architecture. For example, in a call center, the software system which handles virtual or real circuit switching and management resolves the destination using an algorithm or the like, rather than an unambiguous target.

An embodiment according to the present invention, the control over switching in a circuit switch is partitioned together with intelligent functions.

Intelligent functions include, for example, but are not limited to, optimizations, artificial neural network implementation, probabilistic and stochastic process calculations, fuzzy logic, Bayesian logic and hierarchical Markov models (HMMs), or the like.

A particularly preferred embodiment provides a skill-based call automatic call director for routing an incoming call in a call center to an appropriate or optimal agent. While skill-based routing technologies are known in the art, the intelligence for routing the call is separate from the voice routing call management system. Thus, the prior art provides a separate and distinct process, and generally a separate system or partition of a system, for evaluation of the skill based routing functionality. For example, while the low level voice channel switching is performed in a PBX, the high level policy management is often performed in a separate computer system, linked to the PBX through a packet switched network and/or bus data link.

The present invention, however, integrates evaluation of intelligent aspects of the control algorithm with the communications management. This integration therefore allows communications to be established based on an inferential description of a target, rather than a concrete description, and allows a plurality of considerations to be applied, rather than a single unambiguous decision rule.

An aspect of the present invention therefore proposes an architectural change in the computer telephony integrated (CTI) systems, wherein the CTI host takes on greater responsibilities, for example intelligent tasks, than in known systems. In this case, the host is, for example, a PC server having a main processor, for example one or more Intel Pentium 4 Xeon or AMD Athlon MP processors, and one or more voice channel processors, such as Dialogic D/320-PCI or D/160SC/LS, or PrimeNet MM PCI, or the like. In this type of system, the voice channel processor handles con-

US 10,491,748 B1

19

nections and switching, but does not implement control. The control information is provided by the main processor over, for example, a PCI bus, although some or all control information may also be relayed over a mezzanine bus. Because the actual voice channel processing is offloaded from the main processor, real time response with respect to voice information is not required. Therefore, the main processor may operate and be controlled by a standard operating system, in contrast to a real time operating system. While the control processor does operate under certain latency constraints, these are quite long as compared to the response latency required of the voice channel processors. This, in turn, allows the main processor(s) to undertake a plurality of tasks which are not deterministic, that is, the time required to complete processing of a task is unknown and is not necessarily completed within a time window. However, by using state of the art processors, such as a 3.06 GHz Pentium processor, the amount of processing which may be undertaken, meeting a reasonable expectation of processing latency, is substantial. Thus, operating under the same instance of the operating system, for example sharing the same message queue, as the interface between the main processor and the voice channel processor(s), the system according to the present invention may process advanced and complex algorithms for implementing intelligent control. This architecture reduces the required bandwidth for communications with an external high level management system, as well as the processing load thereon. Likewise, since significant decisions and resource allocations are made within the switching system, the need for high quality of service communications channels between the switching system and management system is also reduced.

In a voice communication system embedded in a traditional PBX-type system, the intelligent algorithm for controlling the voice channels preferably requires minimal access to a disk or mass-storage based database. That is, for any transaction to be processed, preferably either all information is available to the main processor at the commencement of the process, or an initial request is made at commencement of the process, with no additional requests necessary to complete the process, although a stored database may be updated at the conclusion of the process. For example, as a call is received, sufficient information is gathered to define the caller, either by identity or characteristics. This definition may then trigger an initial database lookup, for example to recall a user transaction file or a user profile. Preferably, therefore, a table or other data structure is stored in low-latency memory, for example, double data rate dynamic random access memory (DDR-RAM), which holds the principal parameters and information necessary for execution of the algorithm. Therefore, preferably agent and system status information is present and maintained locally, and need not be recalled for each transaction. Of course, in hardware environments where memory or storage resources are not highly constrained, these may be used as appropriate.

According to one embodiment of the invention, a process is provided for optimizing the selection of an agent within the voice channel switching system. This process is a multi step process. Only the later part of the process generally need be completed in a time-critical fashion, e.g., as a foreground task. The initial part(s) of the process may be implemented over an extended period of time, so long as the data available for transactions is sufficient current to avoid significant errors. It is particularly noted that the present invention is not limited to the routing of voice calls, and in fact may be used to control purely data communications. According to another embodiment of the invention, the

20

processing of communications is generally not time-sensitive, and therefore delays of minutes or hours are tolerable. Indeed, on of the classifications of a communication used to target the communication may represent its time-sensitivity. For example, a real-time caller may have a non-time critical issue. The system may record and/or transcribe a message from the caller, which can then be processed in an email processing queue. Likewise, an email or SMS message may represent a requirement for real-time assistance, and therefore a long turnaround delay may be poorly tolerated; such a communication may be routed to a live agent for immediate handling, as appropriate.

According to one embodiment, a set of skills are first defined, which are generally independent skills, although high cross correlations between skills would not defeat the utility thereof. The skill definitions may be quite persistent, for example over a particular campaign, call center, or even multiple call centers and multiple campaigns. The skills generally are not subject to change after being defined, although through advanced processing or reprocessing of data, clusters in multidimensional space may be defined or revised, representing 'skills'. Likewise, a manual process may be employed to define the skill set. Since one purpose for defining these skill sets is to distinguish between agents, it is preferred that the skill definitions are defined to emphasize the relevant differences, that is, each parameter of a skill set correlates strongly with a discernable characteristic (or set of characteristics) of a call, and that as defined, there is a correlation between a value of that characteristic and success (however defined) in handling a call having the discernable characteristic or set of characteristics. While it is also possible to have a system in which agent characteristics are defined according to measurable criteria, whether or not these vary significantly among agents, and whether or not these correlate strongly with outcome, however in such a case the agent skill set vector would have to be processed for effective usage, and thus may result in inefficiencies in both data acquisition and optimization implementation. Of course, a first stage of agent skill set processing could be performed in advance of the optimization, to produce an intermediate data format having the desired characteristics.

It is also possible for a 'skill' to be arbitrarily defined, that is, a cluster of communications objects which have a common characteristic or set of characteristics are routed to a common destination soon after initial identification, even if that destination is arbitrarily selected.

Next, for any given task, the skills are typically weighted. (In the case of a single relevant skill, the optimization according to the present invention may have limited advantage, while with a plurality of relevant skills, the optimization has a more significant effect). That is, the importance of any skill with respect to the task is defined or predicted. This may also be a manual or automated process. In the case of an automated process for weighting the skills, past tasks similar in nature are analyzed to determine which skills were involved, and to what extent. Typically, since the skill set definitions are normative, the task-skill relationships are derived from data for various or all agents, and need not be limited to the data pertaining to a single or respective agent. The weighting may be adaptive, that is, the weighting need not be invariant, and may change over time based on a number of factors. The weightings may also be time dependent, for example following a diurnal variation.

Each agent may be assigned a metric with respect to each skill. As discussed above, the skill assignment may be arbitrary, as a means to ensure that a cluster of communications are handled together; however, once this decision is

US 10,491,748 B1

21

made, the allocation may be implemented by the ‘skill’ metric. This process may be manual or automated, however, a number of advantages accrue from an automated analysis or assignment of agent skill level. Typically, an initial skill level will be assigned manually or as a result of an off-line assessment. As the agent is presented with tasks, the proficiency of the agent is analyzed, and the results used to define skill-specific metrics. As stated above, since the skill definitions are normative, the skills of one agent are compared or comparable to skills of others. For example, the skill sets are assigned using a multivariate analysis technique, based on analysis of a plurality of transactions, predicting the best set of skills consistent with the results achieved. In this analysis, each skill metric may be associated with a reliability indicia; that is, in some instances, where the outcome of clearly determinable, and a skill as defined is highly correlated with the outcome, the reliability of the determined skill value for a statistically significant sample size is high. On the other hand, where a particular skill is relatively unrelated to the tasks included within the data analysis set, that is, the outcome factor is relatively uncorrelated with the value of the skill, the reliability of a determination of an agent skill will be low.

A related issue relates to inferring an agent skill level for a skill parameter where little or no data is available. For this task, collaborative filtering (also known as social filtering) may be appropriate. A collaborative filter seeks to infer characteristics of a person based on the characteristics of others having similar associated parameters for other factors. See references cited and incorporated by reference above. In this case, there is only a small analytic difference between a parameter for which data is available from a respective agent, but yields an unreliable measurement, and a parameter for which data is unavailable, but can be inferred with some reliability. Therefore, the skill determining process may employ both techniques in a composite; as more data becomes available relating to an actual skill level of an agent with respect to a skill parameter, reliance on inferred skill levels is reduced. It is therefore an aspect of one embodiment of the invention that a collaborative filter is used to infer agent skill levels where specific data is unavailable. It is also an aspect of an embodiment of the invention that in addition to a skill level metric, a reliability estimate for the measurement of the skill level metric is also made available.

In the case of arbitrarily assigned skills, these may also be assigned manually or automatically, based on various criteria.

It is noted that in defining a desired agent profile for a task, the skill metrics themselves are subject to unreliability. That is, the target skill levels themselves are but an estimate or prediction of the actual skills required. Therefore, it is also possible to estimate the reliability of the target skill level deemed desired. Where the target skill level is low or its estimate unreliable, two separate and distinct parameters, the selected agent may also have a low or unreliably determined skill level for that attribute. On the other hand, where a skill is reliably determined to be high, the agent skill profile should also be high and reliably determined.

In other instances, the metric of skill does not represent a quantitative metric, but rather a qualitative continuum. For example, the optimal speech cadence for each customer may differ. The metric, in this case, represents a speech cadence parameter for an agent. The idea is not to maximize the parameter, but rather to optimize it. Therefore, reliability in this instance does not equate to a reduction in estimated magnitude. It is also noted that a further ancillary parameter

22

may be applied for each skill, that is, tolerance to mismatch. For example, while call received by a call center, for technical support, may seek an agent who is more knowledgeable than the caller is with respect to the problem, but not one who is so far advanced that a communication gap would be apparent. Thus, an optimum skill parameter as well as a range is defined. In like manner, other descriptors of a statistical function or distribution may be employed, for example, kurtosis and skew.

It is noted that there are a number of ways of scoring outcome of a call, and indeed, a number of parallel scoring systems may be employed, although they should be consistently applied; that is, if an agent is selected for handling a call based on one paradigm, care should be employed in scoring the agent or the call outcome using a different paradigm. Such cross analyses, however, may be useful in determining an optimum outcome analysis technique.

When a new matter is to be assigned to an agent, the pool of agents are analyzed to determine, based on the predefined skills, which is the best agent. Selecting the best agent for a task is dependent on a method of scoring outcome, as discussed above. In some instances, there is a relatively simple process. For example, agents entrusted to sell a single product can be scored based on number of units sold per unit time, or the time it takes to close a sale. However, where different products are for sale, optimization may look at different parameters, such as call duration, revenues per call or unit time, profit per call or unit time, or the like. As the variety of options for a user grows, so does the theoretical issues involved in scoring an agent.

It is also possible for agents to engage in an auction; that is, agents bid for a caller. In this case, an agent must be sufficiently competent to handle the call based on the information available, and agents with skills far in excess of those required may be excluded from the bidder pool. For example, agents may be compensated on a commission basis. The bidding may involve an agent bidding a commission rate (up to the maximum allowed). In this way, the employer gets the benefit of competition between agents. The bid, in this instance, may be a manual process entered into by the agent as a prior call is being concluded.

The bid may also be automatically generated at an agent station, based on both objective and subjective factors. See, WO 20050290297, expressly incorporated herein by reference, and Steven M. Hoffberg, ‘Game Theory in the Control of Ad Hoc Networks’, Wireless Systems Design 2004 (San Diego, March 8). That is, a bid may be automatically defined and submitted on behalf of an agent. The bid may be defined based on an economic or other criteria. In the case of subjective valuation and bidding, the system may produce objectively inefficient outcomes; however, this is not a defect in the system, since it is not being asked to objectively optimize the outcome. On the other hand, a bidder may be presented with information which represents an objective analysis, and thus permit a user to choose to accept an objectively optimized bid, or to choose a different bid. Ideally, the system is “strategyless”, and thus the typically desired bid will be the objectively optimal one, but in various circumstances, a user may select a different bid, and therefore likely outcome. Rational basis for this different bid include incomplete information held by an automated processor, collusion, or other errors or factors which cause the subjective bid to rationally differ from that presented automatically. The optimization of agent selection may also be influenced (in either an automated or non-automated implementation) by other factors, such as training opportunities.

US 10,491,748 B1

23

Therefore, in determining a cost benefit of selection of a particular agent, a training cost/benefit may also be included.

Thus, according to a simplistic analysis, the agent with the highest score is selected. This is only optimum if we assume that there is uniform incremental cost in selecting each agent, and that the system remains static as a result of the selection. On the other hand, if agent costs differ, or the system status is materially altered on the basis of the selection, or there are extrinsic factors, such as training, then the optimum may also differ. A number of factors may also influence optimality of selection. While most are merely business-based considerations, some may be politically incorrect (bad public policy), or even illegal. For example, an optimization may take into account discrimination on an illegal basis, resulting in harm to either callers or agents within a protected class. That is, a traditionally discriminated-against minority may be subjected to automated and institutionalized discrimination as a result of an algorithm which favors a discriminatory outcome. In fact, the discriminatory outcome may be both efficient and optimal, under an economic or game theory analysis. However, this may be undesired. One way to counteract this is to estimate the discriminatory impact of the algorithm as a whole and apply a global antidiscriminatory factor. While this has the effect of correcting the situation on an overall level, it results in significant inefficiencies, and may result in a redistribution in an 'unfair' manner. Further, the antidiscriminatory factor is itself a form of discrimination.

Another method for approaching this problem is to analyze the profile or skill vectors of the presumably discriminated-against agent or customer classes, and compare this to the corresponding vectors of non-discriminated-against class of agents or customers. Assuming that discrimination occurs on a class basis, then, a corrective factor may be used to normalize components of the vector to eliminate the discriminatory effect.

A further method of remediating the perceived discrimination is through training. In this case, the presumably objective outcome determinations are not adjusted, nor is the 'economic' model for optimal agent selection disturbed. Instead, a mismatch of the skill profile of an agent with the caller is used as an opportunity to modify behavior (presumably of the agent), such that the deficiency is corrected. While the discussion herein generally relates to a set of cooperative agents handling calls from non-cooperative clients, this is not a predicate for use or application of the system and method.

For example, a call center agent may have a characteristically ethnic accent. In one case, the agent accent may be matched with a corresponding caller accent, assuming that data shows this to be optimum. However, assuming that vocal ethnicity relates to socioeconomic status, the result may be that the value of the transaction (or other score value) is associated with this status. The goal would therefore be for the agent to retrain his or her accent, and indeed use a different accent based on an inferred optimal for the caller, or to overcome this impediment by scoring well in transactions involving those other than a 'corresponding' accent. Each of these is subject to modification through agent training. Therefore, it is apparent that the optimization may be influenced by economic and non-economic factors, and the optimization may include objective and subjective factors.

The system may also intelligently analyze and control other aspects of telecommunications besides call routing. For example, it is particularly advantageous to characterize the caller, especially while the call is in the queue. However,

24

increasing the amount of information which must be communicated between the switch control and a high-level system is undesirable, thus limiting the ability to extract low-level information from the caller. Such information may include preferred language, a voice stress analysis, word cadence, accent, sex, the nature of the call (IVR and/or speech recognition), personality type, etc. In fact, much of this information may be obtained through interaction and/or analysis of the caller during the queue period. Further, in some instances, it may be possible to resolve the caller's issues without ever connecting to an agent, or at least to determine whether a personal or automated resolution is preferred. According to an aspect of the invention, the switch itself may control and analyze the interaction with the caller. Advantageously, the switch may further perform a sensitivity analysis to determine which factors relating to the call are most useful with respect to selecting an appropriate agent, and more particularly by limiting this analysis to the agents within the pool which are likely to be available. Further information characterizing the user may also be gathered to construct a more detailed user profile.

It is noted that, in some cases, a caller prefers to remain passive in the queue, while in other instances, the caller would prefer to actively assist in optimizing the experience. This does not necessarily correlate with a universal caller profile, nor the optimal selection of agent. This can be quickly ascertained, for example through IVR. It is further noted that an efficient analysis performed by the switch may differ from an efficient analysis performed or controlled by a high level system. For example, a high level system may employ speech recognition technology for each caller in a queue. The switch, on the other hand, would likely not be able to implement speech recognition for each caller in a large queue internally. Further, since the profile of the caller and the correspondence thereof to the agent skill profile, as well as the correlation to the outcome, is dependent on the selection of characteristics for analysis and outcome metric, the parameters of each, according to the present invention, will also likely differ.

Returning now to the problem of routing a call using an intelligent switch, the condition of optimality in the case of equal incremental cost, a stationary system condition as a result of the selection, and scalar skill parameters having a magnitude correlated to value, is denoted by the formula: $A_n = \max \sum (rs_i a_n s_i)$, which denotes that Agent 'n' is selected by maximizing the sum, for each of the required skills s_i , of the product of weighting for that skill rs_i , and the score for agent n $a_n s_i$.

As stated above, this optimization makes two very important, and not always applicable assumptions. First, more highly skilled agents often earn higher salaries. While, once scheduled, presumably the direct cost is fixed, over the long term, the pool of agents must be adjusted to the requirements, and therefore the selection of an 'expensive' agent leads to increased costs. On the other hand, by preferentially selecting the skilled agent over the unskilled agent, the job experience for the skilled agent may be diminished, leading to agent retention problems. Likewise, the unskilled agent is not necessarily presented with opportunities for live training. Thus, it is seen that the agent cost may therefore be a significant variable.

The formula is therefore modified with a cost function as follows:

$$A_n = \max [Ac_{n1} \sum (rs_i a_n s_i) + Ac_{n2}],$$

wherein Ac_{n1} and Ac_{n2} are agent cost factors for agent n. To determine the anticipated cost, one might, for example,

US 10,491,748 B1

25

divide the daily salary by the average number of calls per day handled by the agent. This, however, fails to account for the fact that the average length of a call may vary based on the type of call, which is information presumed available, since the skill set requirements are also based on a classification of the type of call. Further, an agent highly skilled in some areas may be relatively unskilled in others, making an average call duration or average productivity quite misleading. Another cost to be considered is training cost. Since this is generally considered desirable, the actual value may be negative, i.e., an unskilled trainee may be selected over a highly skilled agent, for a given call, even though the simple incremental agent costs might tend toward a different result. Likewise, selection of an agent for a certain call may be considered a reward or a punishment for good or bad performance, and this may also be allocated a cost function. The key here is that all of these disparate factors are normalized into a common metric, 'cost', which is then subject to numeric analysis. Finally, the optimization may itself evolve the skill sets and cost function, for example through training and reward/punishment. The cost of the 'connection' between a caller and an agent may also be considered, for example in a multi-location call center, or where agents are compensated on a per-call basis.

Another factor to be considered in many cases is anticipated outcome. In some instances, the outcome is irrelevant, and therefore productivity alone is the criterion. On the other hand, in many cases, the agents serve a business purpose, and call outcomes may be graded in terms of achieving business goals. In many instances, the business goal is simple an economic parameter, such as sales volume, profit, or the like, and may be directly computed within a cost function normalized in economic units. On the other hand, some business goals, such as customer satisfaction, must be converted and normalized into economic terms prior to use in an optimization. In any case, the expected outcome resulting from a particular agent may be added as a factor in the cost function.

Another factor to consider in making a selection of an agent in a multi-skill call center is the availability of agents for other calls, predicted or actual. Thus, while a selection of an agent for one matter may be optimal in a narrow context, the selected agent might be more valuable for another matter. Even if the other matter is predicted or statistical, in some instances it is preferred to assign more specialized agents to matters that they can handle, rather than assigning multitasked agents. This is represented as follows:

$$A_n = \max \{ ([Ac_{n1} \sum (rs_i q_n s_i) + Ac_{n2}] + B_{cn}) + Cc_n + Dc_n \},$$

wherein Bc represents a term for the anticipated change in value of agent n as a result of the selection, Cc represents a term which indicates the anticipated value of the transaction resulting from the selection of agent n, and Dc represents the opportunity cost for allocating agent n to the particular call.

In the case of competing requests for allocation, a slightly different formulation of the problem may be stated. In that case, one might compare all of the cost functions for the matters in the queue with respect to each permissible pairing of agent and matter. Instead of selecting an optimal agent for a given matter, the system selects an optimal pairing of respective multiple agents with multiple matters. In the case of a call center, often the caller hold time is considered a basic criterion for selection. In order to weight this factor, for example, the cost function includes an allocation for caller hold time, and possibly a non-linear function is applied. Thus, a caller may be taken out of order for pairing with an optimal agent. In some cases, the variance of a parameter is

26

also considered, in addition to its mean value. More generally, each parameter may itself be a vector, representing different aspects.

It is noted that the various factors used in the system may be adaptive, that is, the predicted values and actual values are compared, and the formula or variables adjusted in a manner which is expected to improve the accuracy of the prediction. Since outcome is generally measured in the same metric as the cost function, the actual cost is stored along with the conditions of the predictive algorithm, and the parameters updated according to a particular paradigm, for example an artificial neural network or the like. Typically, there will be insufficient data points with respect to a system considered static to perform an algebraic optimization.

The present invention provides cost function optimization capabilities at a relatively low level within the call routing system. Thus, for example, prior systems provide relatively high level software, operating on massive customer relations management (CRM) database systems, to seek optimization. On the other hand, according to the present invention, the parameters are supplied in advance, generally in a batch format, to the low level routing and computer integrated telephony (CTI) software, which computes the cost functions. Call outcome data is generally available during and after a call to the high level software, which can then set or adjust values as necessary for the future. It is noted that, generally, the architecture according to the present invention would not generally provide agent scheduling information, since this represents a task separate from the call routing functions. Therefore, known systems which integrate both tasks are typically distinguished from the present invention. However, it would be possible as a separate process for this to be performed on the telephony server according to the present invention. More generally, the updating of agent skill tables or a database, and agent scheduling and call center management, are performed on high level systems which are discrete from the telephony server. These systems typically access large databases, generate reports, and integrate many different functions independent of the communications functions.

The advantage of a preferred architecture according to the present invention is that when a call is received, it can be routed in real time, rather than after a possibly significant delay. Further, this data processing partition reduces data communications bandwidth requirements and reduces transactional load on the CRM system. In addition, this architectural partition reduces the need for the CRM system to be involved in low level call management, and reduces the need for the CTI software to continually interact with the high level CRM software. This, in turn, potentially allows use of simple architecture CTI platforms using standard operating systems.

According to a preferred embodiment, the matter skill requirements, agent skill data, and other parameters, are provided to the CTI software, for example as an ASCII table. The CTI software may, for example, invoke a subprocess for each call received or in the queue, to determine the then-optimum agent selection, for a local optimization, i.e., a selection of the optimal agent without regard for the effect of this selection on other concurrent optimizations. In order to globally optimize, the processing is preferably unitary. As conditions change, for example, further calls are added to the queue, or calls are completed, the optimizations may be recomputed.

For example, in a call center with 500 agents, each classified with respect to 32 skills, with an average of 2000 calls in the queue, with about 50 agents available or antici-

US 10,491,748 B1

27

pated to be available at any given time, the computational complexity for each optimization is on the order of 160×10^6 ($2000 \times 50 \times 50 \times 32$) multiplies, generally of 8 bit length. A 2 GHz Pentium 4 processor, for example, is capable of theoretical performance of about 2400 MFLOPS. Using a simplified calculation, this means that less than about 10% of the raw capacity of this processor would be required, and more powerful processors are being introduced regularly. For example, a 3.06 GHz Pentium 4 processor with 'hyper-threading' has recently been introduced. In fact, in real-world situations, the processor would likely not be able to achieve its benchmark performance, but it is seen that a single modern processor can handle, in near real time, the required processing. Coprocessing systems are available which increased the processing capability, especially with respect to independent tasks, while allowing all processes to be coordinated under a single operating system. For example, Microsoft Windows and Linux both support multiprocessing environments, in case increased processing capacity is required. On the other hand, if a high level CRM system is interrupted to process each call event to globally reoptimize agent selection, and communicate this with the CTI software, a significant communication and transaction burden would be encountered. Thus, the present invention proposes that the skill-based call routing algorithm be executed in conjunction with the low level CTI process, as an integral part of the call routing function. Likewise, other call-process related algorithms may be implemented, in addition to or instead of a call routing calculation.

Advantageously, for example in many non-adaptive systems, no high level CRM system is required, and the entire skill-based routing functionality may be implemented in the CTI system, saving significant hardware expense and software complexity. Thus, where the cost function is relatively simple to calculate, the skills required for the call and the skills of each respective agent well known and relatively constant, a simple database may be provided for the CTI platform to route calls intelligently.

Another aspect of the invention provides optimization of communications management based on adaptive parameters, e.g., not only on the existing skills of the respective agents, but rather also based on an anticipated or predicted change in the agent's skills as a result of handling the call. Likewise, when considering an overall cost function for optimizing call directing, any variety of factors may be considered within its context. Therefore, it is another object to provide a consolidated cost function for communications management, wherein pertinent factors or parameters are or may be expressed in common terms, allowing unified consideration. According to a preferred embodiment of the invention, this is handled at a low level within the communications management system, although various aspects may be handled in real time or otherwise at various levels of the communications management system.

In the case of real time communications, such as traditional voice telephony, the switching must by definition occur in real time, so must the resolution of the parties to the communication. Therefore, another aspect of the invention involves communications and coordination in real time of the various system components, including the low level system. Preferably, the data upon which an optimization is based is available locally to the low level system before a real time communication is received, so that external communications to resolve the target are minimized. In some cases, communications with other system components will

28

still be required, but preferably these do not require essentially non-deterministic systems to respond prior to resolution.

Another aspect of the invention seeks to optimize long term call center operations, rather than immediate efficiency per se. Thus, at various times, the system performs functions which are different or even opposite the result expected to achieve highest short term efficiency. Preferably, however, during peak demand periods, the system assures high short term efficiency by switching or adapting mode of operation.

Therefore, according to the present invention, a number of additional factors are applicable, or the same factors analyzed in different ways, beyond those employed in existing optimizations. Since most call centers are operational for extended periods of time, by analyzing and optimizing significant cost factors beyond those contemplated by the prior art, a more global optimization may be achieved.

In a service environment, the goal is typically to satisfy the customer at lowest cost to the company. Often, this comes through making a reasonable offer of compromise quickly, which requires understanding the issues raised by the customer. Delay leads to three costs: the direct and indirect operations cost; the possibility of increased demands by the customer (e.g., impaired business marginal utility of the communication); and the customer satisfaction cost.

In technical support operations, the agent must understand the technical issues of the product or service. The agent must also understand the psychology of the user, who may be frustrated, angry, apologetic, or even lonely. The agent must often remotely diagnose the problem, or understand the information provided by the caller, and communicate a solution or resolution.

In some instances, these seemingly abstract concepts are represented in relatively basic terms at the communications server level. For example, the cadence of a speaker may be available by a simple analysis of a voice channel for silence and word rate. Stress may also be represented in a spectral analysis of voice or in other known manner. Alcoholism or other impairment may be detected by word slurring, which may also be detected by certain signature patterns in the voice pattern.

It is noted that, in some instances, the skill related parameters are not independent. That is, there is a high cross correlation or other relationship between the parameters. In other instances, there are non-linearities in the process. A simple summing of magnitude times weight for these parameters may introduce errors. Therefore, a more complex algorithm may be employed, without departing from the spirit or scope of the present invention.

Likewise, for each caller profile class, a different optimization may be employed. There are some traits, such as alcoholism, which may alter the optimal selection of agent, all other things being equal.

Therefore, communications routing on seemingly sophisticated or abstract concepts may be efficiently handled at a low level without interrupting the basic call processing functions or requiring non-standard hardware. In this sense, 'non-standard' refers to a general purpose type computing platform performing the communications routing functions. In fact, efficiency is generally enhanced according to the present invention by avoiding the need for remote communications of the call parameters and the resulting communications and processing latencies. Of course, in certain tightly coupled environments, the target resolution may be performed on a physically separate processor or system from

US 10,491,748 B1

29

the low level call processing, without deviating from the essential aspects of embodiments of the invention.

In many cases, the caller characteristics and issues will often have a significant effect on the duration of the call. While, in general, more skilled agents will have a higher productivity, in some cases, the caller restricts throughput. Therefore, even though the agent is capable of completing the call quickly, the caller may cause inordinate delays. According to the present invention, through a number of methods, the caller characteristics are determined or predicted, and an appropriate agent selected based on the anticipated dynamic of the call. Thus, for example, if the anticipated call duration for a successful outcome, based on the caller characteristics is a minimum of 5 minutes (depending on the agent), then an agent who is likely to complete the call in about 5 minutes may be selected as the optimum; agents who would be able to complete the call within 4 minutes, while technically more productive, may have little impact on the actual call duration, and thus would be inefficiently employed. Likewise, an agent anticipated to complete the call in 6 minutes might be deemed inefficient, depending on the availability of other agents and additional criteria. The call may be selected as a training exercise. In this case, an agent is selected for training whom would be expected to operate with a certain degree of inefficiency to complete the call. In some cases, unsupervised training is instituted. In other cases, a training agent (or automated system) is allowed to shadow the call, providing assistance, instruction and/or monitoring of the trainee agent during the call. In this case, it would be anticipated that the call duration would be greater than 5 minutes, due to the training nature of the call. Further, the required trainer assistance further reduces immediate efficiency. However, as the agents in the pool become more skilled, long term efficiency increases.

Preferably, these characteristics are extracted through an analysis, by the communications control system, of the available data, although where appropriate, reference to higher level systems may be performed. Thus, in an interactive voice (or key) response system, there may be sufficient time and resources available to query a high level system for data or request analysis relating to a call. However, in many instances, significant analysis may be performed using the computing resources and information available to the low level communication processing system. Even where the information is not available, a DNIS or other type of lookup may provide this information based on a relatively simple query.

More highly skilled agents are both worth more and generally command higher compensation. A program which trains agents internally is either required, due to lack of specific external training programs, or is cost effective, since new hires can be compensated at a lower rate than trained and experienced hires. Thus, for long-term operations, there is an incentive to train agents internally, rather than seeking to hire trained agents. Therefore, according to another aspect of the invention, such training, past present and/or future, is monetized and employed in optimization of a cost function.

Agents may receive additional compensation for training activities, either for their training activities, performance based compensation based on the improvement of their trainees, or both. Thus, there is an incentive for agents to become skilled and to assist in the training. As a result, the average skill level and uniformity in a call center will increase. However, since the optimal skill palette within a call center typically is a moving target, the training process will never cease.

30

Often, live interaction is an important component of training. Therefore, a significant component of the training encompasses interaction with callers in real-world situations. Training often involves presenting agents with new challenges and experiences in order to assure breadth of exposure.

According to prior skill-based routing schemes, an agent skill level is considered a static upper limit on capabilities, and the ACD avoids distributing calls to agents below a threshold. Agents may be called upon to serve requests within their acknowledged skill set. Likewise, this allows a simple and discrete boundary condition to be respected in the optimization according to the present invention.

On the other hand, according to some embodiments of the present invention, each call is considered a potential training exercise, in order to expand the capabilities of the agent, and therefore the boundary is not concretely applied. Therefore, to the extent that the nature of the call can be determined in advance, the incentive according to this scheme is to route the call to an agent who is barely capable of handling the call, and to avoid routing only to the best available agents. This strategy has other implications. Because agents are challenged continually, there is reduced incentive for an agent to limit his skills to avoid the 'tougher' assignments. Further, a self-monitoring scheme may be implemented to determine the status of an agent's skill with each call. For example, agent performance is typically determined on a call-throughput basis, since call centers are managed on a man-hour requirement basis and agents compensated on a per-hour basis. Therefore, based on a presumed agent skill set and an estimation of the skills required for a given call, a call duration may be predicted. The actual duration is then compared with the predicted duration, providing a performance metric for the agent.

This scheme also allows determination of the pertinent factors for call duration, both based on the information about the call or caller and the skill set of the agent. Thus, a variety of low-level data may be collected about a volume of calls, which may be statistically or otherwise analyzed to determine significant relations. For example, an artificial neural network or fuzzy-neural network may be implemented based on the data, which may then be automatically analyzed based on the independent criteria, e.g., call duration, cost function, or the like.

It is noted that, during peak demand periods, reduced productivity due to training exercises is preferably minimized. Thus, as demand increases, high skill set agents are preferably reassigned from training to most-efficient operational status, while lower skill set agents are assigned to calls well within their capabilities. Thus, during such peak demand periods, the staffing requirement will generally be no worse than traditional call centers. On the other hand, since training is integrated with operations, over a period of time, the average skill of all agents will increase. Thus, more skilled agents will be available at peak periods, reducing overall staffing requirements over a long term due to an expected decrease in average call duration and increase in agent productivity.

According to this embodiment of the invention, it is less critical to perform the call routing resolution in the low level system, since the real time criteria is not particularly limited by processing and communication latencies. On the other hand, corresponding skill routing functions may be performed by the communications processing system for both outbound and inbound communications, thus permitting a simplification of the external supporting systems.

US 10,491,748 B1

31

An embodiment of the present invention provides an Internet Protocol based communications architecture, permitting geographically dispersed physical communications locations to act as a single coordinated entity. In order to centrally manage a queue, the various pieces of information must be available for processing. As noted above, an interactive optimization may require a real time comparison of all available agents. In this architecture, in cases of an ad hoc organization or peak demand periods, freelance agents may be called upon dynamically as required. Thus, if a peak demand period is much shorter than an agent shift, off-site freelance agents may be dynamically called upon, for example through the Internet, ISDN, POTS, DSL, Cable modem, or a VPN, to handle calls. In this case, the optimal training of such off-site or freelance agents will generally differ from those who are in-house agents. For example, if freelance agents are called upon only during peak demand periods, these agents will be trained specifically for the skills in short supply during such periods, or for generic skills which are commonly required.

In order to gage the skill set required of an agent for a call, a number of methods may be employed. Using a menu or hierarchal menu, a series of questions may be asked of callers in the queue to determine the identity of the caller and the nature of the call. Likewise, ANI/DNIS information, IP address or the like, or other communications channel identifier may be employed to identify the calling telephone communications channel. This information may directly indicate the characteristics or desired characteristics of the communication, or be used to call an external database record associated with the identity of the caller or communications channel. While it is possible to associate such a database closely with the low level communications processing system, this is not generally done, since it may impair the deterministic characteristics of the communications processing system. Rather, if such information is required by the low level communications system for resolution, and cannot be stored locally in a data table, it is preferred that it be available through a closely coupled, but independent system. As discussed above, it is preferred that a call entering the queue require no more than a single database query and receipt of response prior to action, although other non-time critical access may occur both before and after action. The prior art, on the other hand, generally provides such information through independent and generally high level systems. High level systems are generally characterized by general purpose interfaces, broad range of functionality, and often a communications protocol having a rich and complex grammar. On the other hand, tightly coupled systems can often forgo extensibility and interoperability in favor of efficiency.

In many instances, call centers are implemented to provide support for computer systems. It is known to provide a message automatically generated by a computer to identify and report the status of the computer at a given time, and possibly the nature of a computer problem. One aspect of the present invention allows this message to be associated with a direct semantic communication session with the user, for example to predefine the nature of the call and possibly the skill set required to address the issues presented. Thus, for example, a caller may be prompted to specify information of particular relevance in the routing process, while not being prompted for information irrelevant to the selection. For example, if only one agent is available, the entire prompting process may be bypassed. If two agents are available, their profiles may be analyzed, and only the most critical distinctions probed. This entire process may be handled in the low

32

level communications processing system, without substantial loss of efficiency or throughput in that system, and with substantial gains in overall architectural efficiency.

Often, a highly skilled agent will serve as mentor for the trainee, and 'shadow' the call. Thus, the routing of a call may depend on availability of both trainee and skilled instructor. This dual-availability checking and pairing may be performed in the low level system.

Another aspect of call center efficiency impacted by this scheme is agent motivation. Because an agent with lower skill levels will be given assignments considered challenging, while more skilled agents given training assignments which may be considered desirable, there is an incentive for agents to progress, and likewise no incentive to avoid progressing. Thus, an agent will have no incentive to intentionally or subliminally perform poorly to avoid future difficult skill-based assignments. These factors may be accommodated in a cost function calculation, for example with an update of the agent vector after each call based on call characteristic vector, call outcome and duration, chronological parameters, and the like.

In operation, the system works as follows. Prior to call setup, the nature of the call is predicted or its requirements estimated, as well as the prospective issues to be encountered. This may be performed in standard manner, for example in an inbound call based on the number dialed, based on the ANI/DNIS of the caller (with possible database past history lookup), selections made through automated menus, voice messages, or other triage techniques. In the case of outbound calls, a database of past history, demographic information (both particular to the callee and for the region of the call), and nature of the call may all be used to determine the projected agent skill set required for the call. Alternately, only parameters available locally to the communications control system are employed, which, for example, may exclude a past history database lookup. Collaborative filtering may be used to assist in inferring a profile of a remote user.

It is noted that, after initial call setup, the actual skill set required may become apparent, and the call may be rerouted to another agent. For example, this may be performed at a high level, thus permitting correction of errors or inappropriate selections made by the low level system.

Once the predicted skill sets are determined, these are then compared against a database of available agents and their respective skill sets. A weighting is applied based on perceived importance of selection criteria, and the requirements correlated with the available agent skill sets.

When the call center is operating below peak capacity, marginally acceptable agents may be selected to receive the call, possibly with a highly acceptable agent available if necessary for transfer or handoff or to monitor the call. When the call center is operating near peak capacity, the agents are assigned to minimize the anticipated man-hour burden (throughput) and/or wait time. Thus, peak throughput operation generally requires that agents operate within their proven skill sets, and that training be minimized.

Each call is associated with a skill expression that identifies the skills that are relevant to efficient handling of the call. As previously noted, the preferred embodiment is one in which more than one relevant skill is identified, so that all of the factors that determine a 'best' agent for handling a call can be considered. This is expressed, for example, as a call characteristic vector. The relevant skills required may be determined using different techniques.

The skill expression of a call includes the required skills and skill levels for efficiently handling the call. In one

US 10,491,748 B1

33

embodiment, the skills may be divided into two categories: mandatory and optional skills. Mandatory skills are those skills that an agent must possess in order to handle the call, even if the call remains in queue for an extended period of time. For example, language proficiency is often a mandatory skill for handling a call. Optional skills are those that are considered in the selection of the appropriate agent, but not critical. In operation, these mandatory skills are expressed as a high relevance rating with respect to a call characteristic having a non-linear (e.g., binary or sigmoid) characteristic. Therefore, in the absence of exceptional circumstances, other factors for qualified agents will determine resolution. Alternately, the mandatory skills may be specified as a pre-filter, with optional skills and cost function expressed through linear-type equations.

It is noted that the peak/non-peak considerations may be applied on a call-by-call basis. Thus, certain callers may be privileged to have a shorter anticipated wait and greater efficiency service than others. Thus, these callers may be treated preferentially, without altering the essential aspects of the invention.

The present invention may also generate a set of reports directed to management of the call center. Typically, the communications server generates a call log, or a statistically processed log, for analysis by a higher level system, and does not generate complete, formatted reports itself. The quality of service reports are generated to indicate the effectiveness of the call-management method and system. An agent summary report is organized according to the activities of particular individuals, i.e. agents. A skill summary report organizes the data by skill expressions, rather than by agents. This report may list the number of calls requiring selected skill expressions and the average time spent on those calls. Other known report types are also possible. An important report type is the improvement in call center efficiency over time, i.e., decreased wait time, increased throughput, increased customer satisfaction, etc. Thus, each agent should demonstrate improved skills over time. Peak throughput should meet or exceed reasonable expectations based on a statically skill-routed call center. Other metrics may also be evaluated. Such reports are typically not generated from low level communications systems, and are considered an inventive feature.

It is therefore an object of the invention to provide a communications control system comprising an input for receiving a call classification vector, a table of agent characteristic vectors, and a processor, for (a) determining, with respect to the received call classification, an optimum agent selection based on at least a correspondence of said call classification vector and said table of agent characteristic vectors, and (b) controlling a call routing of the information representing said received call in dependence thereon. It is a further object of the invention to provide a system wherein the process maintains a table of skill weights with respect to the call classification, and applies said weights to determine an optimum agent selection.

Another object of the invention is to provide a communications control system for handling real time communications, wherein an integral system resolves a communications target based on an optimizing algorithm and establishes a communications channel with the resolved communications target.

A further object of the invention provides a communications method comprising receiving a call, classifying the call to determine characteristics thereof, receiving a table representing characteristics of potential targets, determining an optimum target based on the characteristics of both the call

34

and the potential targets, and routing the received call to the optimum target, the determining step and the routing step being performed by a common platform.

A still further object of the invention provides a communications control software system, comprising a multithreaded operating system, providing support for applications and for passing messages between concurrently executing applications, a communications control server application executing under said multithreaded operating system, for controlling real time communications, and at least one dynamically linkable application, executing under said multithreaded operating system, communicating with said communications control server application to receive call characteristic data and transmit a resolved communications target.

Another object of the invention provides a method of determining an optimum communications target in real time, comprising receiving a communication having an indeterminate target, selecting an optimum target, and establishing a channel for the communication with the optimum target, wherein said selecting and establishing steps are performed on a consolidated platform.

It is a further object of the invention to provide a communications processing system for directly establishing and controlling communications channels, receiving information regarding characteristics of a preferred target of a communication, comparing the characteristics with a plurality of available targets using an optimizing algorithm, and establishing the communication with the target in dependence thereon.

It is another object of the invention to provide a method of selecting a call handling agent to handle a call, comprising the steps of identifying at least one characteristic of a call to be handled; determining a call center load, and routing the call to an agent in dependence on the characteristic, call center load, and agent characteristics.

A further object of the invention provides a method optimizing an association of a communication with an agent in a communications center, comprising the steps of determining a characteristic of a communication; accessing a skill profile of a set of agents; cost-optimizing the matching of the communication with an agent based on the respective skill profile, and routing the call to a selected agent based on said cost-optimization with a common system with said optimizing.

An object of the invention also includes providing a method for matching a communication with a communication handler, comprising the steps of predicting a set of issues to be handled during the communication; accessing a profile record for each of a plurality of communications handlers; analyzing the profile records with respect to the anticipated issues of the communication to determine a minimal capability; selecting an optimum communication handler; and controlling the communication, all controlled within a common process.

The foregoing has outlined some of the more pertinent objects of the present invention. These objects should be construed to be merely illustrative of some of the more prominent features and applications of the invention. Many other beneficial results can be attained by applying the disclosed invention in a different manner or modifying the invention as will be described. Accordingly, other objects and a fuller understanding of the invention may be had by referring to the following Detailed Description of the preferred embodiment.

The present invention improves efficiency, and facilitates use of communications resources which are special purpose,

US 10,491,748 B1

35

especially with respect to cost, specialization, and/or skill set, within an automated process.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention and the advantages thereof, reference should be made to the following Detailed Description taken in connection with the accompanying drawings in which:

FIGS. 1 and 2 are flow charts showing a skill routing method according to the present invention;

FIGS. 3, 4, 5, and 6 show tables representing analysis of 5 agents with 10 skill scores;

FIG. 7 shows a combinatorial analysis of agents versus callers with respect to the data of FIG. 5;

FIG. 8 shows a table representing analysis of 5 agents, 5 rule vectors, and 10 skill scores; and

FIG. 9 shows a combinatorial analysis of agents versus callers with respect to the data of FIG. 8.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

The Detailed description of the invention is intended to describe relatively complete embodiments of the invention, through disclosure of details and reference to the drawings. The following detailed description sets forth numerous specific details to provide a thorough understanding of the invention. However, those of ordinary skill in the art will appreciate that the invention may be practiced without these specific details. In other instances, well-known methods, procedures, protocols, components, and circuits have not been completely described in detail so as not to obscure the invention. However, many such elements are described in the cited references which are incorporated herein by reference, or as are known in the art.

For each agent, a profile is created based on manual inputs, such as language proficiency, formal education and training, position, and the like, as well as automatically, based on actual performance metrics and analysis, and used to create a skills inventory table. This process is generally performed in a high level system, such as a customer relations management system or human resources management system. A profile thus represents a synopsis of the skills and characteristics that an agent possesses, although it may not exist in a human readable or human comprehensible form.

Preferably, the profile includes a number of vectors representing different attributes, which are preferably independent, but need not be. The profile relates to both the level of ability, i.e. expertise, in each skill vector, as well as the performance of the agent, which may be a distinct criterion, with respect to that skill. In other words, an agent may be quite knowledgeable with respect to a product line, but nevertheless relatively slow to service callers. The profile, or an adjunct database file, may also include a level of preference that call management has for the agent to handle transactions that require particular skills versus transactions that require other skills, or other extrinsic considerations.

This table or set of tables is communicated to the communications server. Typically, the communications server does not create or modify the agent skills table, with the possible exception of updating parameters based on immediate performance. For example, parameters such as immediate past average call duration, spoken cadence, and other statistical parameters of a call-in-progress or immediately past concluded will be available to the communications

36

server. These parameters, which may vary over the course of a single shift, may be used to adaptively tune the profile of the agent in real time. Typically, however, long term agent performance is managed at higher levels.

FIG. 1 shows a flow chard of an incoming call routing algorithm according to a preferred embodiment of the present invention. A call is placed by a caller to a call center 301. The call is directed, through the public switched telephone network, although, calls or communications may also be received through other channels, such as the Internet, private branch exchange, intranet VOIP, etc. The source address of the call, for example the calling telephone number, IP address, or other identifier, is received to identify the caller 302. While the call is in the waiting queue, this identifier is then used to call up an associated database record 303, providing, for example, a prior history of interaction, a user record, or the like. The call waiting queue may be managed directly by the telephony server. In this case, since the caller is waiting, variable latencies due to communications with a separate call management system would generally not interfere with call processing, and therefore may be tolerated. In other instances, an interactive voice response (IVR) system may be employed to gather information from the caller during the wait period.

In some instances, there will be no associated record, or in others, the identification may be ambiguous or incorrect. For example, a call from a PBX wherein an unambiguous caller extension is not provided outside the network, a call from a pay phone, or the like. Therefore, the identity of the caller is then confirmed using voice or promoted DTMF codes, which may include an account number, transaction identifier, or the like, based on the single or ambiguous records.

During the identity confirmation process, the caller is also directed to provide certain details relating to the purpose of the call. For example, the maybe directed to 'press one for sales, two for service, three for technical support, four for returns, and five for other'. Each selected choice, for example, could include a further menu, or an interactive voice response, or an option to record information.

The call-related information is then coded as a call characteristic vector 304. This call characteristic is either generated within, or transmitted to, the communications server system.

Each agent has a skill profile vector. This vector is developed based on various efficiency or productivity criteria. For example, in a sales position, productivity may be defined as sales volume or gross profits per call or per call minute, customer loyalty of past customers, or other appropriate metrics. In a service call, efficiency may be defined in terms of minutes per call, customer loyalty after the call, customer satisfaction during the call, successful resolution of the problem, or other metrics. These metrics may be absolute values, or normalized for the agent population, or both. The skill profile vector is stored in a table, and the profiles, which may be updated dynamically, of available or soon to be available agents, are accessed from the table (database) 305.

Typically, the table 305 is provided or updated by a high level call center management system to the communications server system as the staffing assignments change, for example once or more per shift. Intra-shift management, such as scheduling breaks, may be performed at a low or high level.

The optimization entails analysis of various information, which may include the caller characteristics, the call incident characterization, availability of agents, the agent profile(s),

US 10,491,748 B1

37

and/or various routing principles. According to the present invention, the necessary information is made directly available to the communications server, which performs an optimization to determine a 'best' target, e.g., agent selection, for the caller.

For example, if peak instantaneous efficiency is desired, for example when the call center is near capacity **306**, more advanced optimizations may be bypassed and a traditional skill based call routing algorithm **307** implemented, which optimizes a short term cost-utility function of the call center **308**. An agent who can 'optimally' handle the call is then selected **309**, and the call routed to that agent **310**. The global (e.g., call center) factors may be accounted as a separate set of parameters.

Thus, in order to immediately optimize the call routing, the general principle is to route the call such that the sum of the utility functions of the calls be maximized while the cost of handling those calls be minimized. Other types of optimizations may, of course, be applied.

According to one optional aspect of the invention, the various routing principles discussed above explicitly value training as a utility of handling a call **311**, and thus a long-term optimization is implemented **312**. The utility of caller satisfaction is also weighted, and thus the agent selected is generally minimally capable of handling the call. Thus, while the caller may be somewhat burdened by assignment to a trainee agent, the call center utility is maximized over the long term, and call center agents will generally increase in skill rapidly.

In order for the communications server system to be able to include these advanced factors, they must be expressed in a normalized format, such as a cost factor.

As for the cost side of the optimization, the cost of running a call center generally is dependent on required shift staffing, since other costs are generally constant. Accordingly, a preferred type of training algorithm serves to minimize sub-locally optimal call routing during peak load periods, and thus would be expected to have no worse cost performance than traditional call centers. However, as the call center load is reduced, the call routing algorithm routes calls to trainee agents with respect to the call characteristics. This poses two costs. First, since the trainee is less skilled than a fully trained agent, the utility of the call will be reduced. Second, call center agent training generally requires a trainer be available to monitor and coach the trainee. While the trainer may be an active call center agent, and therefore part of the fixed overhead, there will be a marginal cost since the trainer agent might be assuming other responsibilities instead of training. For example, agents not consumed with inbound call handling may engage in outbound call campaigns.

It is clearly apparent that the communications server system will have direct access to call center load data, both in terms of availability of agents and queue parameters.

Thus, in a training scheme, an optimization is performed, using as at least one factor the value of training an agent with respect to that call **312**, and an appropriate trainee agent selected **313**.

In order to provide proper training, the trainer and trainee must both be available, and the call routed to both **314**. Generally, the trainee has primary responsibility for the call, and the trainer has no direct communication with the caller. Therefore, the trainer may join the call after commencement, or leave before closing. However, routing a call which requires two agents to be simultaneously available poses some difficulties. In general, the trainer is an agent capable of handling the entire call alone, while the trainee may not

38

be. Therefore, the trainer is a more important participant, and the initial principle in routing the training call is to ensure that a trainer is available. The trainer may then await availability of an appropriate trainee, or if none is immediately available, handle the call himself or herself.

On the other hand, where a specific training campaign is in place, and a high utility associated with agent training, then the availability of a specific trainee or class of trainees for a call having defined characteristics is particularly important. In that case, when an appropriate trainee is available, the call held in that agent's cue, and the call possibly commenced, awaiting a training agent's availability.

If the training is highly structured, it is also possible to assign the trainer and trainee agents in pairs, so that the two are always available for calls together.

The system according to the present invention may also provide reinforcement for various training. Thus, if a subset of agents receive classroom training on a topic, the server may target those agents with calls relating to that topic. For example, the topic may represent a parameter of a call characterization vector. In order to target certain agents for calls having particular characteristics, a negative cost may be applied, thus increasing the probability that the agent will be selected, as compared with an agent having a positive cost. By using a single cost function, rather than specific override, the system becomes resilient, since this allocation is not treated as an exception, and therefore other parameters may be simultaneously evaluated. For example, if a caller must communicate in a foreign language, and the agent does not speak that foreign language, then the system would not target the call to that agent, even if other factors weigh in favor of such targeting.

The same techniques are available for outbound campaigns and/or mixed call centers. In this case, the cost of training is more pronounced, since agents idle for inbound tasks are generally assigned to outbound tasks, and thus the allocation of trainer agents and trainee agents generally results in both longer call duration and double the number of agents assigned per call. This cost may again be balanced by avoiding training during peak utility outbound calling hours and peak inbound calling hours; however, training opportunities should not be avoided absolutely.

According to one embodiment of the invention, at the conclusion of a call, the caller is prompted through an IVR to immediately assess the interaction, allowing a subjective scoring of the interaction by the caller without delay. This information can then be used to update the stored profile parameters for both caller and agent, as well as to provide feedback to the agent and/or trainer. Under some circumstances, this may also allow immediate rectification of an unsatisfactory result.

Example 1

Each agent is classified with respect to 10 skills, and each skill can have a weight of 0 to 127. The skill weights may be entered manually by a supervisor, developed adaptively, or provided by other means. These are sent as a parameter file to the communications server.

A rule vector specifies a normalized contribution of each skill to apply to the total. This rule vector, for example, represents the call characteristic vector. Thus, attributes of the call and the status of the system are analyzed to generate this rule vector. There can be more than one rule vector defined in a project (split), or a rule can be setup in a per call basis. Generally, routing with predefined rules is much more

US 10,491,748 B1

39

efficient than routing with rules in a per call bases. When a call needs to be routed to an agent, the rule vector is applied to the skills of the available agents and a score is derived for each agent. The agent with the highest score is assigned the call.

As shown in FIG. 3, Agent 1 would be selected, since this is the highest score.

In this example, it is presumed that all selections have the same cost, and therefore the utility only varies. Thus, the agent with the highest utility function is the optimal selection.

Example 2

The conditions below are the same as in Example 1, except two new factors are provided, Ac1 and Ac2. The Preliminary Score is calculated as the sum of the products of the Rule Vector and the Agent Vector. The Final Score is calculated as $(Ac1 \times \text{sum}) + Ac2$.

In this case, Ac1 represents an agent-skill weighting cost function, while Ac2 represents an agent cost function. Since we select the maximum value, more expensive agents have correspondingly lower cost values.

As can be seen, in FIG. 4, Agent 5 is now optimum.

Example 3

In this example, a limiting criterion is imposed, that is, only agents with a skill score within a bound are eligible for selection. While this may be implemented in a number of ways, possibly the simplest is to define the range, which will typically be a lower skill limit only, below which an agent is excluded from selection, as a preliminary test for 'availability'.

As shown in FIG. 5, the screening criteria may be lower, upper or range limits. In this case, the screening process excludes agents 2, 3, and 5, leaving agents 1 and 4 available. Of these two choices, agent 1 has the higher score and would be targeted.

Example 4

In this example, the optimization seeks to optimize the placement of 5 incoming calls to 5 agents. As shown, each caller is represented by a different call vector, and each agent by a distinct skill vector. The optimization therefore seeks the maximum utility from the respective possible pairings.

Using a combinatorial analysis, the maximum value is 62.42, which represents the selection of agent 1/caller 1; agent 2/caller 5; agent 3/caller 4; agent 4, caller 2; and agent 5, caller 3. See FIGS. 6 and 7.

Example 5

Similarly to Example 4, it is also possible to include an agent cost analysis, to provide an optimum cost-utility function. As in Example 2, the cost factors (CF) are reciprocal, since we select the largest value as the optimum. Likewise, time factors (TF) are also reciprocal, since we seek to minimize the time spent per call. In this case, the cost analysis employs three additional parameters: the agent cost, a value representing the cost of the agent per unit time; a value representing an anticipated duration of the call based on the characteristics of the caller; and a value representing the anticipated duration of the call based on characteristics of the agent.

40

As can be seen in FIGS. 8 and 9, the maximum value is 314.78, which corresponds to a selection of:

Agent 1/Call 5; Agent 2/Call 1; Agent 3/Call 4; Agent 4/Call 2; and Agent 5/Call 3.

Therefore, it is seen that the optimum agent/caller selection is sensitive to these cost factors.

It is also seen that, while the analysis can become quite complex, the formulae may be limited to evaluation of simple arithmetic functions, principally addition and multiplication, with few divisions required. Thus, these calculations may be executed efficiently in a general purpose computing environment.

From the above description and drawings, it will be understood by those of ordinary skill in the art that the particular embodiments shown and described are for purposes of illustration only and are not intended to limit the scope of the invention. Those of ordinary skill in the art will recognize that the invention may be embodied in other specific forms without departing from its spirit or essential characteristics. References to details of particular embodiments are not intended to limit the scope of the claims.

Example 6

Geographic information may be used as a basis for communications routing. Mobile phones are or will be capable of geolocation, meaning that the location of the handset may be automatically determined in real time and communicated. Likewise, a location of landlines can typically be determined. There are a number of instances where this information may then advantageously be used to route calls. For example, a call to a national pizza delivery chain toll free number or central facility may be automatically routed to a geographically proximate local franchisee, or, if a number are available, to one of a qualified group. It is noted that while the communications are preferably voice communications, other type of communications may be supported.

However, it is also possible to perform evaluation of more complex algorithms in order to determine a set of communications partners. For example, a geographic factor, a past history, and/or user profile may be available to describe the caller. This information may provide, for example, a preferred language, a contact report (identifying likely issues), demographic information, and user personality (as determined from a prior communication). Likewise, an interactive voice or keypad response system can glean further information to determine the issues involved in the call. Using this information, a vector may be provided describing the caller and the likely issues of the call, which may then be used to optimize a targeting of the call to available recipients. The maintenance of vectors to describe available call targets is described above.

In cases where multiple recipients are available and have, within a reasonable range, equivalent or super-threshold qualifications or suitability to receive the call, it may be appropriate for the potential recipients to compete for the call. That is, the optimization of targeting (e.g., pairing of a caller and callee) includes an economic component, optionally with a non-economic component. For example, the potential recipients each submit a bid for the call, with the call being routed to the auction winner (which may be a payment to or from the recipient, depending on the circumstances of the auction) at, for example, a first or second price, according to the auction rules.

In a typical case, the routing server has a direct and prearranged financial arrangement with the bidders, and the

US 10,491,748 B1

41

auction process does not directly involve the caller. On the other hand, other cases allow the caller to be involved in the auction as a 'buyer' or 'seller', with the communications router serving only in the capacity of auctioneer, and not a principal to the auction.

In cases where the potential recipients do not all have equivalent qualifications, a normalization function may be applied to correct the bids. For example, a potential recipient with a 60% match with the required qualification profile might have to bid 50% more than a potential recipient with a 90% match, assuming that the matching function linearly corresponds with an economic factor; otherwise, a non-linear normalization may be applied. This is equivalent to providing that the value applied to determine the auction winner includes a component representing an economic value and a component representing a non-economic value, e.g., a match or optimality score for the call, which is determined for each bidder to determine the winner. The bidder in this case may either have knowledge of the match score, or may bid blind.

In a commission based system, for example, an agent with a higher sales average performance might have to bid a lower amount than an agent with lower performance, the difference being an amount which tends to equalize (but not necessarily completely equalize) the anticipated payoff from the call, thus incentivizing higher sales performance. In any case, the communications router (or a separate system which communicates with the communications router in some embodiments) evaluates the bids including both economic and non-economic components, determines the winning bidder, and determines the communications path(s).

In another embodiment, a group of agents within a call center have performance goals for a shift, with possible gradation between agents of the goals based on compensation, seniority, etc. The agents are within a queue, in which the default is a sequential selection of available agents. However, an agent may seek to take a break, and therefore bids for a lower position within the queue. Likewise, an agent may find him or herself behind in performance, and wish to bid for higher placement within the queue. As discussed above, the bid cost or perturbation effect may be normalized based on a variety of factors and schemes, including the optimality of matching. In this scheme, the auction may be economic or non-economic. In a non-economic scheme, each agent is provided with a set of bid units, for example 100 per shift. The bid units may then be applied to advance within the queue, or even traded with another agent (although this possibility leaves open the issue of undesired indirect real economic effects, since the trade may involve extrinsic value).

Another possibility is the ad hoc formation of chat groups. In this case, the composition of the group is optimized based on the respective profile vectors of the members. In some cases, the ideal or optimum is minimum variance of the vectors, but in other cases optimality may require complementary components. Assuming multiple chat groups and multiple callers, there may be a market economy for matching a caller with a group. In such a scenario, a VCG type auction may be conducted, with the composition of each group allocated based on an optimization of bid values. An example of this is a sports chat line. A number of fans and sports celebrities contact a call center and are identified and a profile applied. Using market principles, the groups are formed to maximize the utility aggregate functions. Thus, a group of 'high rollers' may gain the benefit of a superstar, while neophytes may only communicate with a rookie, with the set of groups optimized to achieve maximum utility.

42

An automated chat system may also be used for dating services, adult theme entertainment, business services, consumer services, or the like. In these systems, the communications router typically taxes some of the economic surplus generated by the system, in a real economic form, while benefiting the various classes of user.

It is noted that the auction may involve transfer of real economic benefits, or a synthetic economy constructed within a closed system. For example, micropayment technologies may be employed to authorize and convey the value between entities, even through an open network, without having to trust all entities within the chain of custody.

The bidding may be a volitional real time event, allowing those involved to make decisions on the spot; but more typically, a bidder will define a personal value function, which is then used in an automated auction process. The bidder will therefore provide an indirect control over the bidding on his or her behalf, for example using feedback to tune the attributed value function to a desired value. In action types where broadcast of a true value is a dominant strategy, the function itself may be presented as a bid (assuming that the auctioneer has sufficient information to evaluate the function), otherwise, it may be evaluated under the circumstances and a normalized value transmitted. The auctioneer is, in this case, the communications arbitrator or switch. In a successive price auction, the value function itself is preserved, although the dropout pattern may be noted, allowing an estimation of the value function of competitors.

It should be clear that there are many possible scenarios which allow callers and/or potential recipients to compete for a connection, and therefore a large variety of auction types may be implemented accordingly.

The present system differs from a known telecommunications auction in that, for example, it is sensitive to user characteristics, and does not treat each communications line as a simple commodity.

Example 7

The system and method according to the present invention is not limited to voice communications, or even human-to-human communications. Rather, it permits a cost-benefit optimization in various communications environments where predetermined (i.e., before the communication is established) characteristics of a both a source and a destination make arbitrary targeting or association inefficient. The present invention therefore exploits this available information to optimize a cost-benefit or cost-effectiveness of the association, as compared to the cost-benefit or cost-effectiveness of competing allocations.

For example, a proxy server or load balancing server may seek to formulate communications based on a set of rules or correspondence between parameters. These communications can be human-to-human, human-to-machine, machine-to-human, machine-to-machine, or multiparty (e.g., >2 parties) communications. In one example, a "dating" or "contact" site is established which permits communications, which may remain anonymous, allowing an inferential targeting of a communication based on a "best fit", "optimal fit", "cost efficient", or other criteria. The communications may involve selection of a best target, best available target, best target with compensation for anticipated availability, optimal target, most cost effective target, or other criteria. On the other hand, where multiple communications are to be simultaneously considered, the desired result may not be the

US 10,491,748 B1

43

optimal target for each source, but rather the highest efficiency or cost-effectiveness on a community basis. Where more than two parties are included in a communication, a combinatorial optimization, such as a Vickrey-Clarke-Groves (VCG) optimization may take place, using automated approximations of value functions or permitting a “bidding” by each participant of either its price or payment, depending on whether it anticipates a gain or loss as a result of involvement. If only two parties are involved, a bidding may still occur, and thus a VCG auction may be implemented in all cases, even if the result is somewhat trivialized in certain cases. It is noted that, while an economic or cost optimization may be used as an underlying theory for linking communications, it is not necessary in all cases to employ currency, or an exchange of currency, as a basis for implementing the result. It is therefore understood that the present invention is not limited in the type of the valuation criteria, or indeed the nature of the characteristics to be evaluated. Rather, an aspect of this embodiment of the invention is that there is at least one non-economic parameter which must be normalized with other parameters which may require the same or different normalization (e.g., into a dimensionless or “economic” fungible quantity) in order to control the communications.

Preferably, this determination is performed as an integral function of the router, that is, the routing function is defined by the predetermined information available about the source and available targets, rather than by explicit addresses. While ultimately, the communication may be defined by explicit addresses or identifications, use of descriptive information or implicit targeting information earlier in the process permits more intelligent and flexible decisions, and thus allows the system to produce acceptable or more optimal results in a broader range of circumstances.

In determining the pairing (or in some cases, associating of larger groups), it is preferred that each communicating unit have a characteristic vector, providing sufficient information regarding the value, cost or price of the communication, and the benefit or requirements of the communication. Typically, the benefit or requirements will not be a single parameter, but rather will represent a multi-parametric matrix (i.e., vector). Even if the benefit or requirements is expressed in a single parameter, typically there will be a statistical error associated with that parameter itself, thus yielding a potentially complex analysis of seemingly simple data, such as a data set represented by a single descriptor. Expressed mathematically, the input vector A may be interpreted as the vector B for targeting

$$A = \begin{pmatrix} 0 & 0 & 0 \\ 0 & 1 & 0 \\ 0 & 0 & 0 \end{pmatrix},$$

$$B = \begin{pmatrix} \pm 0.10 & \pm 0.05 & \pm 0.10 \\ \pm 0.01 & 1.00 \pm 0.20 & \pm 0.05 \\ \pm 0.15 & \pm 0.20 & \pm 0.20 \end{pmatrix}.$$

The meaning of these vectors is that vector A is sparsely populated, with only $A_{2,2}$ having a non-zero value. On the other hand, in the vector B, each value is associated with its own probability distribution, and cannot necessarily be

44

ignored. Indeed, in some cases, the value is non-parametric, and incapable of a null attribute.

In a cost-effectiveness optimization, the benefit or result must be expressed in dimensionless (cost) terms, using a net valuation function. Typically, the initial data will not be expressed as cost, and indeed may be subject to a dynamic translation or market exchange rate. When there are a plurality of attributes, each must be evaluated for its contribution to the cost function. The net value, under the conditions of evaluation, is then compared with other valuations, typically under those same conditions of evaluation, though in some cases, slightly different conditions may apply to each evaluation because of passage of time or other factors. The set of allocations which maximizes the net value to the community is the one which represents the cost-benefit optimum.

Thus, another aspect of the present invention provides comparison of vectors which change over time, and which are subject to different base times and/or different predicted change over time. The vectors are corrected by predicting a state at a relevant time, using at least one of a tendency of the vector to change, or a population statistic which predicts changes given an initial state, or a combination of both techniques. Likewise, there may be a blend between population basis and individual basis as information regarding the individual element which is described by the vector and information about the population accumulates. Note that, as information about the individual accumulates, its association with a subpopulation may increase or decrease, and thus the population basis need not be considered a static benchmark.

In another example, a system is provided which allocates limited resources, such as cache memory, persistent storage, logistical support, and bandwidth to a set of ‘users’. Each respective resource has an associated cost, which may be static or dynamic in nature. In a particular circumstance encompassed by the present invention, the grouping of the resources is not independent, and thus the system cannot simply allocate each type of resource independently. Rather, the resources are allocated in blocks or units, each having a set of resources of the various types.

Likewise, each user has a set of requirements or characteristics of various types, and a cost, value or satisfaction function. For example, a given user requires various portions of the types of limited resources. Typically, the aggregate demand (at zero cost) for the resources will exceed the supply, thus making them ‘limited’. In some cases, especially where resources have an incremental cost or utility, additional resources or types of blocks or units may be recruited or retired in dependence on the ‘market’ value.

The user may itself be an automated system, and indeed may also have resources allocated on a cost-efficient basis.

Returning now to a discussion of the targeting vector, this vector is defined in advance of the communication or portion of a sub-communication, and is therefore intended to be predictive of the cost and benefits of the resulting communication. Since this prediction may be inaccurate, or simple subject to probabilistic expression, in some cases the association of the source and destination will be dependent on not only the mean value of a characteristic, but also its probabilistic expression or distribution. Therefore, even in cases where the mean values permit an efficient match, the probability of an actual mismatch, and the associated costs if this were to occur, should also be considered, in formulating the optimum outcome. Expressed mathematically, let us assume that the outcome of a transaction is expressed as a binary satisfaction value.

US 10,491,748 B1

45

If there is a 90% chance of satisfaction with cost 1, and a 10% chance of satisfaction with cost 20 with one possible pairing, the net cost is 2.9. If, in another possible pairing, there is a 95% chance of satisfaction with cost 2, and a 5% chance of satisfaction with cost 15, the net cost is 2.65. Thus, in this simple example, the later has the lower anticipated cost, even though in many cases, the actual cost of the first allocation will be lower. It is therefore useful to understand and correctly model these types of statistical processes, since they can affect outcome, and lead to paradoxical losses in efficiency.

When the satisfaction function and/or valuation function are continuous functions, the result is analogous, but the evaluation somewhat more complex. Likewise, the satisfaction functions may be interdependent and in the case of human users, typically subjective. However, to the extent it can be modeled, it is subject to a cost optimization.

It is generally a premise of this type of optimization that perfection or complete satisfaction is neither obtainable or even desired. Thus, this type of optimization generally provides little benefit where resources are essentially unlimited or independently allocated. Likewise, where all requests or targets are symmetric, or modeled as being so, gains will also be limited. The present invention therefore exploits information relating to the differences between association of partners or groups, in conjunction with evaluable cost-benefit functions, to generate an optimum allocation.

Example 8

The present invention may be used to target communications of various types, wherein the targeting information is inferential and context-dependent, and therefore the actual recipient of the communication may remain indeterminate until the time for resolution. Therefore, the targeting information need not be a correspondence of “skills” and “likely subject”. Rather, the method would provide utility for resolving various ambiguities or indeterminateness.

One example is email, fax, instant messaging, or other correspondence to a generic address, which must then be handled by a selected person or agent. While availability of a target is generally an issue, in non-interactive voice communications, real time availability need not be a critical concern.

One characteristic of the invention is that an optimization, often of an NP-complete type, is required to determine the best allocation with respect to a “cost function”, and the optimum condition cannot reasonably be determined by a single mathematical function involving the input data.

In many communications environments, including voice, email, instant messaging, fax, etc., a particular problem involves unsolicited communications, which may be simply time consuming (e.g., “spam”), or possibly malicious (e.g., “virus”, “phishing”, etc.). Various methods are available to score communications for their likely characteristics. However, such undesired communications are variant, and tend to evolve, and may be quite similar to desirable communications. For even a single recipient, a set of roles or contexts may be defined. If incoming communications are classified according to a correspondence to these roles or contexts, possibly with an adaptive bias. Instead of simply scoring the communication to make a binary “undesired”/“desired” decision, the classifier seeks a best fit, in a competitive environment. A number of different biases may be applied. For example, a predetermined proportion, number or limit of distribution may be estimated in advance. In most cases, a classification is exclusive, though communications may also

46

be multiply classified. In general, classifications are made statistically or probabilistically.

For example, 100 email communications may be received by a single email account for processing. A set of rules may permit definitive processing of, e.g., 50% of the communications, such as white lists, black lists, banned words/phrases, spam signatures, authentication technologies, etc. On the other hand, the remaining 50% of the communications require an “intelligent” classification. For example, while most people consider emails that include the words “mortgage”, “cialis” or “teens” to be spam, there are persons, roles or contexts in which such words are not definitive clues as to appropriateness. Therefore, simply banning these words may lead to errors; likewise, relying on the presence of these words to effectively filter will also lead to errors, since typographic illusions are often used to convey the meaning without using the literal string as a cue. An internist may indeed receive a number of desired communications which discuss drugs. A home buyer may need a mortgage, or have solicited communications from a mortgage broker. A high school student may regularly have communications which include the word “teens”. Therefore, the role and/or context of the user is a relevant factor.

The classifications themselves may be predetermined or variant or adaptive in class definition and number. After classification, these may be aggregated, or remain separate.

Instead of requiring a resolution of the targeting/classification problem for each email, instead, an algorithm may be provided to operate on a group of communications, with the result being a best classification as a competitive process between the communications and the targets. That is, the typical problem with spam is not that a communication itself is malicious (though this is also a potential problem), but rather that the numerosity of the communications is overwhelming. Therefore, the process proposed by the present invention permits limited leakage of communications, at a manageable number. The steps taken by the user after receipt of the communications may also be used to provide feedback to the classifier, and therefore such feedback typically requires acquisition of data relating to marginal objects. For example, if a user processes are part of a normal workflow all of the objects passed, this leads to an inferred relaxation of a restriction, since no object which is treated as irrelevant has passed; if there is a strong correlation, e.g., $r > 0.95$ between the treatment of an object by the user and the treatment predicted based on the analyzed characteristics of the object, then the restrictions can be tightened in accordance with the analyzed characteristics.

In other cases, the purpose of the system is not to implement an exclusionary filter, but rather to triage the objects according to a predicted classification. Each classification may be assigned a separate queue, which in a large organization may each be managed and handled by separate agents. Thus, a “content vector” describing the object, and a “skill vector” describing the available targets, may be employed, optionally along with an “availability vector” relating, for example, to queue length and a “cost vector” relating to comparative costs and/or benefits. The various vectors are used in a multifactorial optimization, which in the case of queued objects, may reallocate objects previously queued to a “better” position. While the optimization may be performed incrementally for each object, in fact a batch implementation may be useful where response times are slow. For example, if the normal latency for dealing with an object is 1 hour, optimizations every 15-30 minutes would be reasonable.

US 10,491,748 B1

47

Where a plurality of vectors relating to different and “orthogonal” attributes are employed, it is quite useful to perform a cost optimization, wherein the optimization outcome is based on a normalized metric, such as currency. As is known, a cost function need not be normalized in a financial sense, but the various alternates should all be comparable.

In some instances, the actual cost may be compared with a predicted cost, and the difference (error) used to tune the cost prediction algorithm for improved future performance. In other cases, the ultimate cost may have little to do with the prediction or the information available at the time of prediction, and therefore this tuning process may be inefficient or counterproductive.

Likewise, the actual processing of the objects may be used to provide data for the future allocation of resources; that is, if the available resources lead to a predicted higher overall cost than an alternate resource allocation, steps can be taken to change the allocation in the future. Preferably, the cost function is audited, and long-term performance monitored to ensure that the system does not oscillate or exhibit highly chaotic behavior independent of the objects received, and is stable. Likewise, in some cases, it is also important to analyze the characteristics of objects over time to ensure that the system itself does not cause undesired changes in the objects. For example, if objects having certain characteristics are treated more favorably than others, the objects themselves may evolve to display those more-favorably treated characteristics, without actually changing the underlying nature of the process actually required to deal with the object. This may lead to unfair discrimination, increasing costs, and system instability.

It is therefore seen that the present invention provides a system and method for optimally targeting or matching a set of communications in a system. This system and method is not limited to voice and email communications, and may encompass a broad range of elements to be matched.

The present invention is useful for routing of communications in general, and for optimizing call centers as a particular example of this process. The invention may also be used to optimize handling of Internet communications within an infrastructure where communications may be handled by a plurality of servers, some having different characteristics from other.

It should be appreciated by those skilled in the art that the specific embodiments disclosed above may be readily utilized as a basis for modifying or designing other structures for carrying out the same purposes of the present invention. It should also be realized by those skilled in the art that such equivalent constructions do not depart from the spirit and scope of the invention as set forth in the appended claims.

What is claimed is:

1. A system for assigning communications, comprising a processor and a memory, configured to associate respective communications with respective resources, wherein the memory has stored therein instructions that, when executed by the processor, cause the processor to:

receive a plurality of respective communications;

identify a plurality of resources available for association with a respective communication and capable of handling the respective communication, each available resource having a limited quantitative capacity for association with multiple communications, and an availability state;

calculate a respective score associated with each available resource dependent on the availability state of a respective available resource;

48

estimate an expected economic value to be obtained by associating each respective communication with each respective available resource, dependent on at least the score and a respective communication-content dependent value function of an outcome of a respective communication associated with a respective available resource; and

assign each of the plurality of respective communications to one of the plurality of resources based on at least the estimated expected economic value to be obtained by associating each respective communication with each respective resource.

2. The system according to claim 1, wherein the expected economic value comprises an expected revenue resulting from assigning each respective communication with each respective available resource.

3. The system according to claim 1, wherein the expected economic value comprises an expected profit from assigning each respective communication with each respective available resource.

4. The system according to claim 1, wherein the expected economic value comprises at least one of a cost-benefit and a cost-effectiveness of an association of a respective communication.

5. The system according to claim 1, wherein the availability state is selectively dependent on an estimated wait time before a respective communication is associated with a respective available resource.

6. The system according to claim 1, wherein the plurality of communications each comprise a bidirectional telephone communication.

7. The system according to claim 1, wherein the plurality of resources each comprise a respective call center agent.

8. The system according to claim 1, wherein the estimated economic value to be obtained by associating each respective communication with each respective available resource is determined based on a testing of each possible set of concurrent association of respective communications with respective available resources, consistent with the limited capacity for association with communications of each respective available resource.

9. The system according to claim 1, wherein the association of respective communications to respective available resources results in a persistent change in the expected economic value of a future association of the respective communications to the respective available resources.

10. The system according to claim 9, wherein the assignment of each of the plurality of respective communications to one of the plurality of resources is further based on at least one of a predicted oscillation and a predicted chaotic behavior of the expected economic value of a future association of the respective communications with a respective available resources.

11. A method for assigning communications, comprising: receiving a plurality of respective communications for association with a respective resource selected from a plurality of resources;

identifying a plurality of resources available for association with a respective communication and capable of handling the respective communication, each available resource having a limited quantitative capacity for association with multiple communications and an availability state;

calculating a respective score associated with each available resource dependent on the availability state of a respective available resource;

US 10,491,748 B1

49

estimating an expected economic value to be obtained by associating each respective communication with each respective available resource, dependent on at least the score and a respective communication-content dependent value function of an outcome of a respective communication associated with a respective available resource; and

assigning each of the plurality of respective communications to one of the plurality of resources based on at least the estimated expected economic value to be obtained by associating each respective communication with each respective resource.

12. The method according to claim **11**, wherein the expected economic value comprises at least one of an expected revenue resulting from association of the respective communication, an expected profit resulting from association of the respective communication, an expected cost-benefit resulting from association of the respective communication, and an expected cost-effectiveness resulting from association of the respective communication.

13. The method according to claim **11**, wherein the availability state score is selectively dependent on an estimated wait time before a respective communication is associated with a respective available resource.

14. The method according to claim **11**, wherein the plurality of communications each comprise a bidirectional telephone communication.

15. The method according to claim **11**, wherein the plurality of resources each comprise a respective call center agent.

16. The method according to claim **11**, wherein the estimated economic value to be obtained by associating each respective communication with each respective available resource is determined based on a testing of each possible set of concurrent associations of respective communications with respective available resources, consistent with the limited capacity for association with communications of each respective available resource.

17. The method according to claim **11**, wherein associating of respective communications to respective available resources results in a persistent change in the expected economic value of a future association of the respective communications to respective available resource.

18. The method according to claim **17**, wherein the assigning of each of the plurality of respective communications to one of the plurality of resources is further based on

50

at least one of a predicted oscillation and a predicted chaotic behavior of the expected economic value of a future association of the respective communications with a respective available resource.

19. A method for controlling communications routing, comprising:

receiving information a representing a plurality of communications, a plurality of the communications being concurrently queued for routing, each respective communication involving a respective task dependent on the communication;

identifying a plurality of communication targets available or imminently available for handling a respective communication of the plurality of communications and capable of performing the respective task dependent on the communication, the respective communication targets having a limited quantitative capacity for handling multiple respective tasks;

determining a latency for each of the plurality of communication targets with respect to a respective task to be handled;

estimating an economic value for routing each respective communication to a respective one of a plurality of alternate communication targets, dependent on at least the latency, a consumption of the limited capacity for handling respective tasks, and a communication-content dependent benefit expected to result as an outcome from handling the respective task;

selecting an optimal routing of each of the plurality of communications to a respective alternate communication target dependent on at least a comparison of the estimated economic value for each possible routing of each respective communication to the plurality of alternate communication targets; and

communicating the optimal routing to a communication routing device.

20. The method according to claim **19**, wherein the estimated economic value is determined based on a combinatorial analysis, and is adaptive with respect to a predicted persistent change in the expected economic value of a future routing of at least one respective communication to a respective alternate communication target.

* * * *